NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

U.S. COAST GUARD TELECOMMUNICATIONS PROJECT MANAGEMENT USING THE STRUCTURED APPROACH MODEL

by

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December, 1995

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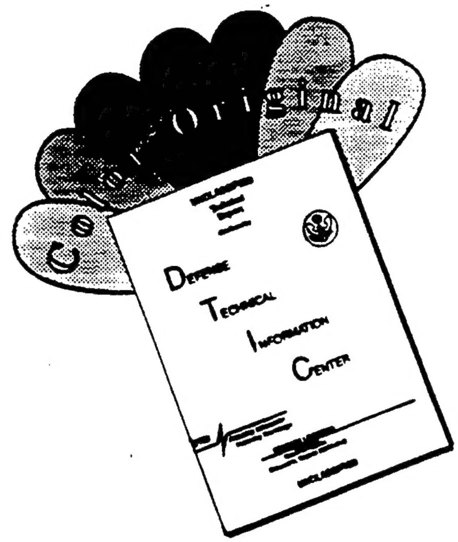

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December, 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE U.S. COAST GUARD TELECOMMUNICATIONS PROJECT MANAGEMENT USING THE STRUCTURED APPROACH MODEL	5. FUNDING NUMBERS
6. AUTHOR(S) Lloyd Lee Stone II	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

The U.S. Coast Guard has been continuously asked to perform more missions with less resources. Technological advances in telecommunications and information systems accessibility have played a major role in the Coast Guard meeting these challenges. However, to meet new demands for even greater efficiency and effectiveness, the Coast Guard strategy for tighter interoperability between Coast Guard commands must continue to evolve. To support this evolution, the Command, Control, and Communication Branch of the Coast Guard must use a strategy for project management that will foster greater efficiency and effectiveness. This strategy should include a standardized approach to project management that fosters communication, attention to detail, and leads to interoperability of systems through standardization without extensively limiting creativity or use of technological advances.

This paper demonstrates how the use of systems thinking, and in particular the Structured Approach Model, can encourage the management characteristics that will lead to the development of more effective telecommunications projects and completion of projects in a more efficient manner. This paper explains the seven phases the Structured Approach Model and views each using the functional, organizational, and physical prospectives. Steps for applying the model are given and are aimed at the Coast Guard project officer.

14. SUBJECT TERMS: Telecommunications Project Management, Structured Approach Model, U.S. Coast Guard, Systems Thinking	15. NUMBER OF PAGES
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

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U.S. COAST GUARD TELECOMMUNICATIONS PROJECT MANAGEMENT USING THE STRUCTURED APPROACH MODEL

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Submitted in partial fulfillment
of the requirements for the degree of

**MASTER OF SCIENCE IN
INFORMATION TECHNOLOGY MANAGEMENT**

from the

**NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The U.S. Coast Guard has been continuously asked to perform more missions with less resources. Technological advances in telecommunications and information systems accessibility have played a major role in the Coast Guard meeting these challenges. However, to meet new demands for even greater efficiency and effectiveness, the Coast Guard strategy for tighter interoperability between Coast Guard commands must continue to evolve. To support this evolution, the Command, Control, and Communication Branch of the Coast Guard must use a strategy for project management that will foster greater efficiency and effectiveness. This strategy should include a standardized approach to project management that fosters communication, attention to detail, and leads to interoperability of systems through standardization without extensively limiting creativity or use of technological advances.

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LIST OF EQUATIONS

LIST OF ACRONYMS AND/OR ABBREVIATIONS

ACAT	Acquisition Category
AIRSTA	Airstation
AMSC	American Mobile Satellite Corporation
AOR	Area of responsibility
ASFO	Air Station San Francisco
Avail.	Available
AWG	Assigned Workgroup
Blkhd	Bulkhead
BYPT	Bay Point
CAMSPAC	Coast Guard Area Master Station, Pacific
CCITT	International Consultative Committee on Telegraphy and Telephony
CCTV	Closed caption television
CEA	Cost-Effectiveness Analysis
CES	Commercial Earth Station
CGDN	Coast Guard Data Network
CGHQ	Coast Guard Headquarters'
CGI	Coast Guard Intelligence
Ch.	Chapter
COM	Computer Output Microfilm
COMMSTA	Communications station
CONUS	Continental United States
CPM	Computerized Project Management
CRC	Cyclical Redundancy Check
$\mathbf{dB_w}$	Decibels (in watts)
DCE	Data circuit-terminating equipment
$\mathbf{D_{mi}}$	Distance in miles

DNA	Digital network architecture
DOP	Development options paper
DTE	Data terminal equipment
DTL	Direct-To-Line multiplex system
EDI	Electronic data interface
ESA	European Space Agency
F_{MHz}	Frequency, in megahertz
Fn	Function
FOM	Figure of Merit
FSL	Free-space loss
FSL_{dB}	Free-Space Loss, in dB
GAE	Generic applications environment
Gbps	Gigabits per second
GHz	Gigahertz
GTE	Generic technology environment
GTP	Generic technology platforms
H x W	Height times width
HDLC	High-Level Datalink Control
HDN	High Speed Data Network
HF	High-frequency
HSTN	High Speed Teletype Network
HVAC	Heating, ventilation, & air conditioning
ILS	Integrated logistics support
Khz	Kilohertz
LES	Land Earth Station
LRC	Form of two-dimensional parity check
Mbps	Megabits per second
MES	Mobile Earth Station

Mgmt	Management
MLC	Maintenance & Logistics Center
MLCP	Maintenance & Logistics Center, Pacific
MSO	Marine Safety Office
NAVAID	Navigational aid
NDS	National Distress System
OSI	Open System Interconnection
OSI	Open Systems Interconnection
OW	Orderwire
PACAREA	Pacific Area
PACINT	Pacific Intelligence
PERT	Performance, Evaluation, & Review Technique
PLP	Packet Layer Protocol
PSTN	Public switched telephone network
RCV	Receive
RDT&E	Research, development, testing & evaluation
SES	Ship Earth Station
SNA	Systems network architecture
STA	Station
T (or t)	Coast Guard's Command, Control, and Communications community (see glossary for complete definition)
TC	Technical capability
TCP/IP	Transmission control protocol/Internet protocol
TOR	Tenantive Operating Requirements
VRC	Form of two-dimensional parity check
VTC	Vessel Traffic Center
VTS	Vessel Traffic System
WBS	Work-Breakdown Structure
Wted	Weighted

XMIT	Transmit
YBIS	Yerba Buena Island

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to outline a structured approach to assist US Coast Guard project officers in developing and planning a major telecommunications system replacement project. This methodology will provide processes to support the project officer in soliciting, documenting, and tracking project requirements using a "systems approach." This thesis will develop methods for completing a baseline assessment, developing a target architecture, and selecting a migration path from available alternative technologies. The selection process will include a cost-effectiveness analysis.

The replacement project for the Coast Guard's Bay Area Communications System (BACS) in the San Francisco area will be used to illustrate the application of this methodology. Where actual data is not available, assumptions (or estimates) will be used for the express purpose of illustrating the methodology.

The purpose of this thesis is NOT to recommend a particular alternative for the BACS replacement project. The purpose is to provide a methodology that encourages project officers to plan and develop their projects using a systems view and provide a number of processes and procedures they can use in doing so.

The primary research questions for this thesis included:

1. How can the structured approach model be used to ensure all aspects of the project are considered?
2. How can the existing functional requirements and any new functional requirements expected to arise over the new system's life-cycle be gathered and documented?

3. How can we track the functional requirements for each site, the physical capacities for each site, and the technological alternatives that can most effectively meet these constraints?
4. Once the alternatives for each site have been documented, how can we choose the most cost effective alternative?
    a) What criteria should be used to select the alternatives?
    b) How should the chosen criteria be weighted for comparison?
    c) Who should develop the criteria weights?
5. What types of resistance to change may arise?
6. What can be done to overcome resistance to change?

B. DISCUSSION

We live in an era of very complex technologies and system interdependencies. To cover all the bases, a project officer must consider a project from many different aspects. Applying an existing list of project considerations is not sufficient, for every project is unique in some manner. A solution rests in the use of "systems thinking" concepts and applying a model that provides an analytical framework on which project officers can build their own list of considerations. The structured approach model provides such a framework for managing a project from conception of customer goals to maintaining the system after installation. This thesis will focus on the planning and development stages of the structured approach model.

A Coast Guard project officer for a telecommunications project has even more complex job than most other project officers. Telecommunications are a part of our basic infrastructure. Changes to the infrastructure affect many different entities, including those in both operational and support roles; therefore, changes to the infrastructure should be undertaken as infrequently as possible. For this to occur, the

infrastructure must be designed to meet the users' needs today and be designed to migrate to meet future needs, with as little disruption to the user as possible.

This takes proper planning and a great deal of knowledge, cooperation, and coordination. The user understands what must be done to complete the missions, but the project officer is the technical expert. The user must help the project officer understand every process used to complete the mission. The project officer must educate the user as to how technology can help him more effectively complete the mission. Together, they must paint a picture of the users systems, as they exist today, and how they may change in the future. This evaluation of the users systems must all take place before any changes to the supporting telecommunications system can even be considered. In other words, how can the project officer design a supporting infrastructure if it is not understood what needs to be supported?

This thesis steps through the phases of the structured approach model only once. But it should be understood that a minimum of two iterations of this model should be completed: once to cover the users systems that ride on the telecommunications system and once for the telecommunications system itself.

The Bay Area Communications System (BACS) replacement project is an optimal project for illustration purposes. It contains most of the challenges faced when replacing a major telecommunications system. It spans some 25 sites spread over hundreds of miles and is located in both urban and rural areas. It has at least 12 customer commands, sponsored by numerous headquarters' and pacific area entities. Site signal demands run the gamut from a few analog signals to multiple T-1's.

C. BACKGROUND

The Coast Guard first installed the Bay Area Communications *Microwave* System between 1985-1987. This system connected 20 different sites using 19 analog microwave links. It was designed to meet the Coast Guard wide area networking (WAN) needs, within the San Francisco area, that existed at the time. The reasons the Coast Guard cited when justifying the construction of the BACS system [Ref. 1, p. 80] were to:

1. improve reliability and transmission quality for voice and data telephone circuits within the San Francisco Bay area;
2. provide all the commands ("units") subordinate to USCG Group San Francisco with the capability to directly communicate with ships, boats, aircraft, and personnel throughout the bay area;
3. provide an alternate routing to deliver textual message traffic between the communications station at Point Reyes, and the district office;
4. replace existing UHF links between the communications station at Point Reyes and the communications center at Coast Guard Island, Alameda;
5. replace existing UHF links between the transmitter and receiver sites at the communications station;
6. reduce FTS (Federal Telephone System) and commercial telephone system recurring costs;
7. provide FTS access to all bay area units;
8. significantly improve communications in the bay area at a lower total life-cycle cost;
9. provide AUTOVON access at a lower cost.

As the Coast Guard WAN requirements have changed over the past decade, at least six major leased lines have been added to the system and one microwave link has been removed. The system is now referred to as BACS and connects 25 different sites. Appendix A contains a chart

depicting the geographic location and inter-connection of the sites served by this system. The BACS interconnects at least 12 different Coast Guard units which have mission-related communications requirements.

The Bay Area Communications System must be replaced for three reasons[Ref.2: p. 2]:

1. the microwave links were built in the mid 1980's and are becoming expensive to maintain;
2. the frequency allocations for the 2 GHz microwave are to be reallocated to meet growing civilian frequency needs;
3. customer requirements have changed and are no longer being met by the existing system.

II. SYSTEMS THINKING AND THE STRUCTURED APPROACH MODEL

A. SYSTEMS THINKING

1. Introduction

Systems thinking has been evolving over the course of the twentieth century and is used in fields as diverse as physical and social sciences, engineering, and management[Ref. 6, p. 68]. Over this period, countless tools and techniques have been developed. Therefore, the scope of this chapter must be limited to presenting the reader with a broad picture of "systems thinking." The intention of this chapter is to:

1. emphasize to the reader the importance of practicing systems thinking;
2. assist the reader in understanding some of the basic principles of systems thinking;
3. generate enough interest that the reader will perform further independent study of the principles of systems thinking. For highly recommended reading material on the subject of systems thinking, see Ref. 3. and Ref. 6.

2. What is Systems Thinking?

To understand systems thinking, we must first define a system. The Webster's dictionary [Ref. 4, p. 1199] defines a system as, "A regularly interacting or interdependent group of items forming a unified whole. Our world is made up of systems. As these systems interact, they create an even larger, more complex, system." For example, the BACS system consists of a microwave system and leased lines which interact together [Ref. 5, p. 1-1]. BACS can also be viewed as part of the Coast Guard telecommunications system used to communicate with internal

and external entities. Viewed in this context, the scope for designing an efficient system greatly increases in both detail complexity and dynamic complexity. Detail complexity exists when many variables must be considered. Dynamic complexity exists when any of the following occur [Ref. 6, p. 71]:

1. when the same action has dramatically different effects in the short run compared to the long;
2. when an action has one set of consequences locally and a very different set of consequences in another part of the system;
3. when obvious interventions produce nonobvious consequences.

Systems thinking is basically the art of understanding how system entities interact. Peter Senge [Ref. 6, p. 6]defines system thinking as:

> "a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static "snapshots." It is a set of general principles...a discipline for seeing the "structures" that underlie complex situations, and for discerning high from low leverage change."

Systems thinking consists of principles and practices. The principles help us to understand the basic causes for resistance to change within a system. The practices, or tools, help us to understand the dynamics at work within a system and find leverage points that can bring about change.

3. How Can it Help the Coast Guard?

The Coast Guard is structured, in a hierarchical manner, like many other bureaucratic institutions, with commands, divisions, branches, and so on. Each with specific areas of responsibility and expertise. This, however, tends to lead to a kind of assembly line mindset. We take what is given to us, apply our expertise, and hand it off to the next one in line. This is done with very little forethought of how

our actions affect the actions, and work, of others. We rarely feel that we can bring changes to "the system," so we continue doing our part and blame the rest of the system for existing inefficiencies.

For example, suppose that a leased line is required for a new system. The project officer requests the line, the telecommunications officer orders the line, and the financial officer pays it. However, there is no mechanism to tract the leased line through its life-cycle. The Maintenance & Logistics Center (MLC) continues to pay for the line as long as it appears on the phone bill. In one instance Maintenance & Logistics Center Pacific (MLCP) found, by chance, that they had been continuously paying for four leased lines that had been disconnected six months earlier [Ref. 7]. In this example, each person did his job as assigned, but the system was not taken into consideration. When we look from each perspective view point, everything seems fine; but when looking at the system as a whole, and the outcome, it is obvious that the system needs fixing.

4. Who Should Apply it?

As leaders in the CG, we must encourage everyone associated with the CG to practice systems thinking. We must take the time to evaluate the ideas and issues that are raised, independent of who raises them.

Programs such as Ideas Express are great motivational tools to encourage the raising of ideas. Additional programs which may raise the level of systems thinking should be carefully considered; however, nothing will work better than a boss willing to take the time to listen and evaluate.

5. Conclusion

The purpose of this section is to encourage others to independently study and apply systems thinking. In these times of shrinking budgets, systems thinking is essential if we are to reach the levels of efficiency and effectiveness demanded of us.

B. STRUCTURED APPROACH MODEL

1. Introduction

Any large design project has many engineering and management considerations which must be tracked in a project file as the project moves forward. This involves both detail complexity and dynamic complexity. The procedures used in this paper are organized using the structured approach model as seen in Figure 1. The structured approach model assists the design team by organizing the major phases to be completed over the system's life-cycle. This aids in tracking project details that have been examined. The model encourages the design team to look at the system from different perspectives. These perspectives form the framework for viewing the project in a "systems thinking" manner. This encourages the design team to consider the whole system during each project phase.

2. The Structured Approach Model

The model consists of eight phases (exterior) and three perspectives (interior). The model breaks the project's life-cycle into eight phases, starting with "organize and plan" and finishing with "maintain system process." Each phase is viewed using the three perspectives: 1) Functional, 2) Organizational, and 3) Physical. Following is a general definition of each of these perspectives, or views [Ref. 2, Module 2]:

Functional: The Functional perspective helps systems engineers and managers understand systems by examining and describing the functions that systems must perform to meet system requirements.

Organizational: The Organizational perspective helps systems engineers and managers understand systems by examining and describing the configuration and the coordination required for systems to function effectively and efficiently.

Physical: The Physical perspective helps systems engineers and managers understand systems by examining and describing the physical resources required by systems to perform their functions.

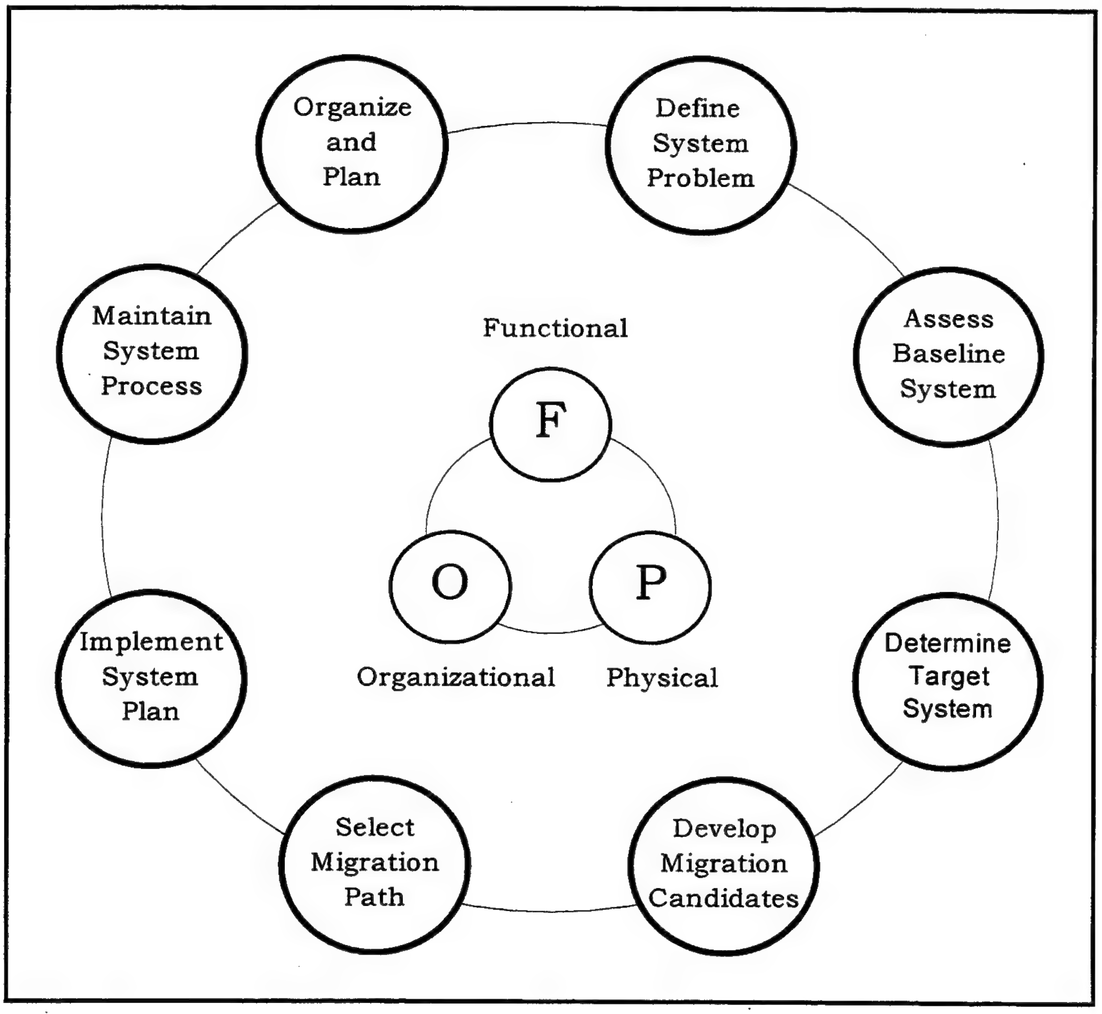


Figure 1: Structured Approach Model; Framework (interior), Phases (exterior)

The structured approach model is based on the model recommended in Volume four of the Department of Defense Technical Architecture Framework of Information Management (TAFIM),

Architecture Concepts and Design Guidance. The TAFIM model differs from the structured approach model by breaking the project into seven phases, instead of eight, and does not take advantage of the perspective framework (interior). In the author's opinion, the inclusion of the perspective framework is the distinct advantage of the structured approach model. It requires the design team to consider the whole system during each phase of the project.

3. How Can it Help the Coast Guard?

Two major problems faced by project officers when dealing with large projects include 1) justifying the decisions made by the design team, and 2) historically recording these decisions and the reasoning behind them. Large projects normally last for years, from conception to completion. Due to military rotations and other factors, personnel turnovers can occur in both the design team and the reviewing/approving hierarchy. With these turnovers, information pertaining to the decisions made may be lost if not documented properly.

Following the model, the project officer should record in the project folder all the information considered by the design team for each perspective, during each phase. This record can be instrumental in the following ways:

1. it can assist the approving officers in understanding the reasoning behind the design team decisions;
2. it will allow entities outside of the design team to raise concerns, or suggest alternatives, not considered by the design team;
3. it will help replacement personnel quickly visualize the project's history, see where the project stands, and comprehend why the project has taken the path it has.

Coast Guard voice and data telecommunications requirements will constantly change as technology evolves and mission, equipment, and software application requirements change. Therefore, the telecommunications system must also evolve to meet these requirements. By following the structured approach model, a migration plan to meet these changing requirements will already exist; however, design teams can only forecast the future with some inevitable uncertainty. As the future becomes more clear, the network manager may have to request adjustments to the migration plan to match the actual environment. A well-documented migration plan provides an historical baseline the network manager can use to compare the evolving organization, functional requirements, and available technologies with those forecast by the design team. The justification for requested changes will be established much more readily by using a comparison to the well-documented baseline than by starting from scratch. The example in Figure 2 illustrates the usefulness of such documentation.

1996: Imagine This...

In the approved plan, the BACS design team has chosen microwave as the optimal technology for the Mount Umunhum remote site. To back up the essential voice circuits, in the event of a microwave system failure, a standby cellular-based system was chosen over a satellite-based system due to estimated costs (cellular: $100/mo., satellite: $150/mo.).

It is now 1999...

The cellular-based system has worked fine, but the actual costs have averaged $125/mo. The network manager does some research and learns that, with the Teledesic and Iridium satellite systems operational since 1998, monthly costs for a satellite-based system have dropped to $100/mo. and would provide twice the data rate of the cellular service. This would allow the new CGXV data circuit to be backed up, in addition to the voice circuits.

From the BACS project folder, the network manager has available all the considerations and estimates used by the design team to justify the cellular system. He can readily make a comparison detailing the changes in environmental factors to justify switching to a satellite-based system.

Figure 2: Illustration of Documentation Effectiveness

4. Conclusion

The structured approach model assists the design team by providing a framework for organizing the major phases of a large engineering project. It encourages the use of systems thinking by providing a method to document project decisions and the reasoning behind them. The documentation will help those outside the decision process to quickly comprehend the project history and the justification used for the path taken.

III. STRUCTURED APPROACH PROCESS: PHASES I & II

A. INTRODUCTION

The structured approach model can be used at a variety of strategic and planning levels. This chapter will briefly discuss the Coast Guard enterprise-wide level, then outline the phases at a project officer/design team level. Although they will normally consist of two separate groups, in this paper the terms "design team" and "Architecture Work Group (AWG)" will be used interchangeably.

B. ENTERPRISE-WIDE STRATEGY

Any project considered by the MLC or HQ unit "t" divisions should correspond, in some manner, to the strategy outlined in the objectives, strategies, and goals established by the Commandant (this includes the program offices). In the Office of Command, Control, & Communications (G-T), strategy is established by the Board of Directors.

Phases I & II are the strategic and system planning phases. Phase I should be completed at the Headquarters level, using the corporate objectives and vision, to build a framework for the Coast Guard's overall IT architecture. Unfortunately, the Coast Guard does not have a well-defined process to gather the IT requirements of the twelve Coast Guard programs (Acquisition(A), Engineering & Development(E), etc.) into an integrated architecture. At this time, Headquarters also lacks the coordination to promulgate a set of standards that can accommodate the various program requirements. Although not currently incorporated by

HQ, the Strategic Approach Model could be of great benefit; they could use it to outline:

1. the missions and goals of each HQ office (organizational view);
2. the functional requirements necessary to meet those goals;
3. the work processes necessary to meet the functional requirements;
4. the high-level standards for applications, data definitions, information platforms, and a telecommunications infrastructure that will lead us in the direction of an integrated target architecture;
5. a migration plan to combine stovepipe IT systems supported by individual programs into an integrated Coast Guard IT system serving all program requirements.

The Maintenance & Logistic Center's Command, Control, & Communications Budget & Planning Division, MLC(tb), should use this high-level framework to define the problem(s) the project will confront and justify the direction the project will take. This could include, but not be limited to:

1. combining requirements of various entities into larger projects;
2. ranking projects to meet priorities as outlined by HQ's strategic business plan;
3. the designing and implementation of projects to enable Coast Guard entities to meet the strategic objectives, as set forth by HQ.

In the event that the strategic business plan is not outlined by their superiors, the project officer must react proactively. Through personal inquiries, the project officer should attempt to ascertain whether the project can incorporate unlisted CG objectives, in addition to the objectives listed in the planning proposal. No project stands alone; its location within the Coast Guard C3 infrastructure must also be accounted for in this phase [Ref. 13, p. 22].

C. PHASE I FOR THE PROJECT OFFICER

The first phase in the Structured Approach Process is the "Organizing and Planning" phase. The purpose of this phase is to develop an initial plan for the process of engineering and managing a system over time. This phase in the systems engineering and management process lays the groundwork for the planning and actions that occur throughout the Structured Approach Process. [Ref. 8, Ch. 6, and Appendix I]

This phase will set the direction for the rest of the project to follow. The final products from this phase include:

1. initial Executive Guidance;
2. the PURPOSE of the system-in-focus;
3. a VISION for the desired system end-state that accomplishes the PURPOSE;
4. an initial PLAN for achieving the VISION;
5. initial Executive Approval and Support. [Ref. 9, p. M3-6]

1. Organizational View

Some of the high-level Mission/Vision strategic drivers for the BACS begin with the Commandant's Direction[Ref. 10]; in particular, Goal #8 states, "Pursue and exploit new technologies to achieve gains in productivity and enhance mission performance." The objectives outlined to meet this goal include:

1. redirect efforts in Research and Development to further mission productivity;
2. use technology to enhance maritime safety, surveillance and environmental systems;
3. be a partner with DOT's R&D efforts to develop integrated smart transportation and navigation information systems;
4. manage Coast Guard information resources.

Each Coast Guard program that inputs or uses data (or communications) carried on the BACS will have requirements which must be considered when developing an infrastructure system such as BACS. The timeframe for meeting the goals set by the Mission/Vision strategic drivers must also be derived.

2. The Enterprise Tasks and Missions

The goals of an enterprise are performance-based. In other words, "how do we want to perform our tasks, and the missions that drive those tasks." This can be seen in the wording of the Commandant's goals; these words include, "redirect," "use," "be," and "manage."

Headquarters sets the Coast Guard-wide goals, but Congress assigns us our missions. The Coast Guard's response to numerous mission requirements can be modeled as a recursive process involving the Coast Guard and Congress. The impact trickles down to BACS. Figure 3 illustrates the relationship between the mission-driven organizational architecture, the generation of new missions, and the requests for resources to meet the new responsibilities.

The Coast Guard's San Francisco Bay area enterprise reflects the results of an evolutionary layering-on of missions. These missions are correspondingly reflected in the functionality of the BACS. The Coast Guard has adopted the policy that the small size of the service dictates that these missions be executed by small, multi-mission units. Each unit carries out multiple tasks, simultaneously or nearly simultaneously, on behalf of separate managers of the various program areas. BACS supports a similarly broad subset of all Coast Guard missions. The external Coast Guard missions BACS routinely supports can be classified in the following categories:

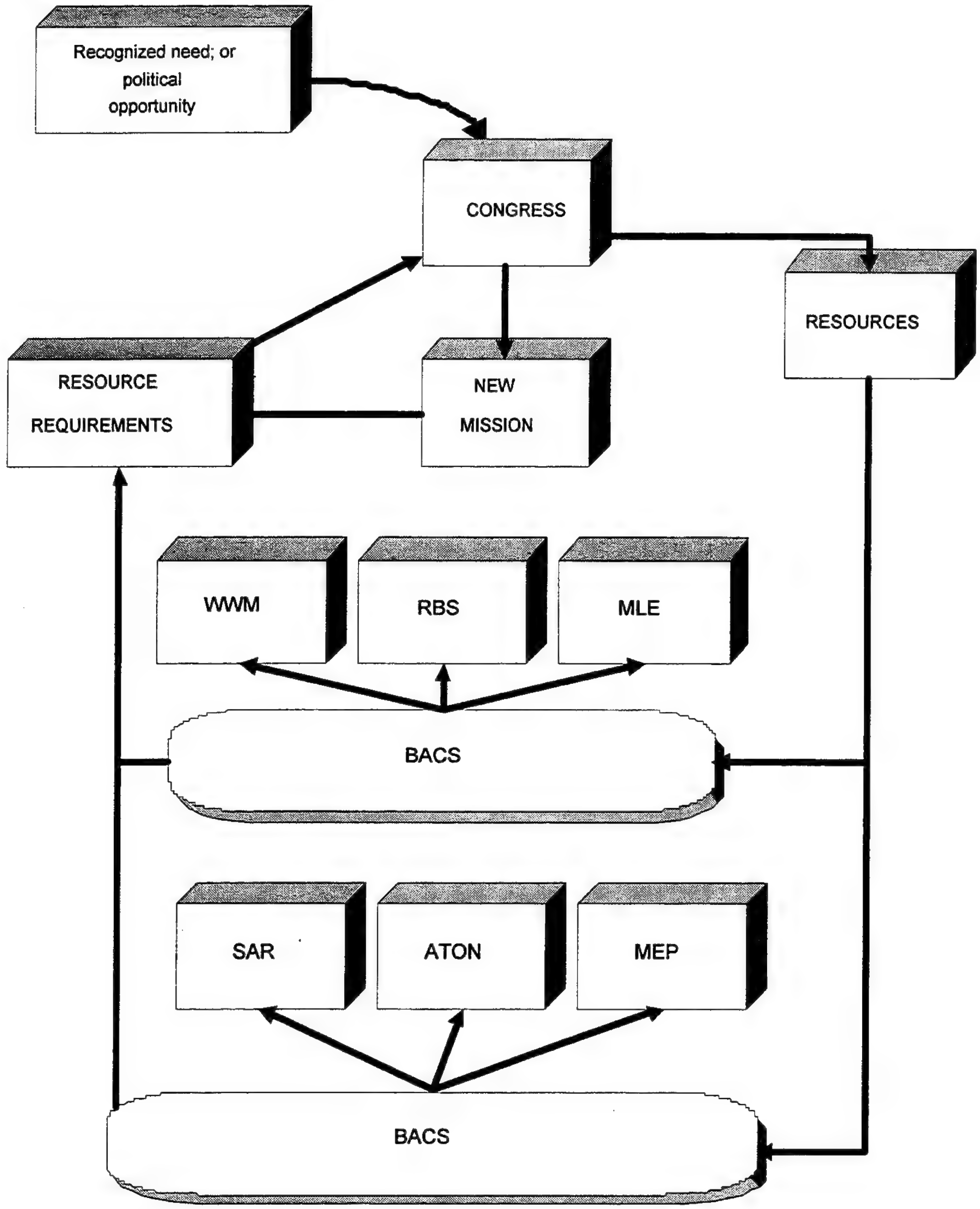
1. *Waterways Management* seeks to develop, implement, and manage vessel traffic movements in congested or high-risk U.S.

waters. Implicit in this definition is the U.S. declared limit of three nautical miles for its territorial sea. The three nautical mile limit bounds the system in focus from a strictly constructed legal perspective. However, as a matter of practicality, customs laws and the military concept of a commander's understanding of the relationship between time and space conspire to extend this bound to the inshore horizon. The waterways management area of operations is analogous to the concept of battlespace developed in the Marine Corps' "Command and Control, FMFM 3."

Authority is exercised in the waterways management mission through promulgation of federal regulations which are either short-lived locally-generated regulations or standing federal regulations. Personnel and a network of sensor equipment also form the Vessel Traffic System (VTS). The VTS continuously monitors certain vessel movements, with the aim of preventing collisions between participating vessels.

2. *Recreational Boating Safety* aims to reduce the risk of injury, loss of life, and property damage associated with the use of pleasure craft in U.S. waters. In addition to numerous other administrative components of the program, the BACS-applicable portion concerns command and control functions exercised over the volunteers of the Coast Guard Auxiliary.

   These auxiliarists volunteer their time and facilities to conduct intermittent search and rescue patrols. When engaged in those activities, their boats and aircraft require a commensurate level of command and control, flight-following, and communications resources. The requirements are met by Group San Francisco, or a subordinate unit, using the communications capabilities inherent in BACS.



WWM - Waterways Management
RBS - Recreational Boating Safety
MLE - Maritime Law Enforcement
SAR - Search and
ATON - Aids to Navigation
MEP - Marine Environmental Protection

Figure 3: BACS/Missions/Resources Illustration

3. *Maritime Law Enforcement* concerns itself with enforcing all applicable federal laws through inspections, interdiction, and searches. The interdiction mission is supported by a large resource-intensive operational effort, and an all-source intelligence effort. Both these elements are major requirements drivers for BACS.

   The law enforcement "battle space" extends globally in the intelligence collection and reporting mission, and operationally with regard to jurisdiction over U.S. flagged vessels.

   The law enforcement mission is also characterized by a requirement for a high degree of interoperability with other agencies and military forces. Since the late 1980s' several DOD Joint Task Forces have been continuously expending resources in counter-narcotics interdiction operations with the Coast Guard, adding their interoperability requirements to those of the many federal law enforcement agencies.

4. *Search and Rescue* includes the planning and execution of resource-intensive missions to locate and recover people and property at sea and along the shore. Some of the associated information systems supporting the search and rescue mission are at the highest end of the Coast Guard's range of information systems complexity. For example, the Coast Guard Data Network component of BACS supports a mainframe-based simulation software product which predicts wind and current-induced drift that a shipwrecked survivor or disabled vessel will experience at sea. This in turn permits the allocation of resource effort to search in the areas of highest probability of detection. BACS is again called upon to disseminate the results of the search planning.

5. *Aids to Navigation* is a mission composed of several distinct elements. Short-range aids include lighthouses, floating buoys, and fixed structures located on or near the water. Some of these devices are monitored via an electronic Automated Control and Monitoring System (AMSC). BACS supports the mission by transporting status reports on the associated lights, signaling devices, and electric generators.

   Long-range aids to navigation are based on several different forms of radio-navigation. The Coast Guard also publishes voice and textual reports informing mariners of hazards and other safety and marine navigation issues for waters in and near the United States. BACS supports the dissemination of this information and the management of the

entire program, and facilitates the collection of a useful series of performance metrics.

6. *Marine Environmental Protection* exists to both prevent and minimize damage to the ecological and economic systems of U.S. ports, waterways, and coastal areas caused by pollution. The mission involves searching for and reporting oil spills, the management of cleanup operations, and the dispersing of vast sums of money for cleanup operations. These responsibilities are carried out by the Captain of the Port through the personnel of the Marine Safety Offices and Marine Safety Detachments.

3. Functional View

The next question is, "what functional requirements are necessary to meet the strategic drivers." These will include requirements such as:

1. reliability requirements;
2. security requirements;
3. types and sizes of signals to be carried;
4. signal timeliness (delay).

To "manage Coast Guard information resources," the requirements should include minimizing maintenance and network manager requirements. Therefore, any new system should include self-monitoring and diagnosing capabilities to a certain component level. To minimize network management, automatic re-routing (upon system failure) and automatic re-initialization (upon system repair) should be required.

4. Physical View

We must now address any high-level issues that will affect the telecommunications architecture. These issues will include any promulgated standards for telecommunications systems and any existing policies or instructions that could affect the project design. The issues of environment and technology availability must also be considered.

D. PHASE II FOR THE PROJECT OFFICER

Phase II in the Structured Approach Process is the "Define System Problem" phase. The purpose of this phase is to structure the system problem so that all subsequent engineering and management efforts will be both effective (*doing the right thing*) and efficient (*doing things right*). This phase in the systems engineering and management process bounds the problem and enables systems engineers and managers to focus on the most important issues and problems....[Ref. 11, p. M3B-1]. The basic product of this phase should include the Tentative Operational Requirement (TOR) paper.

1. Organizational View

Using the organizational view, we need to answer the question, "Organizationally, what cannot occur without the telecommunications project?" These deficiencies can be developed by comparing the strategic drivers to the capabilities of the existing system. Some of the possible strategic drivers could include, but are not limited to, the following:

1. relocation, or reallocation of resources;
2. joint operations with other units and/or organizations;
3. change in mission or role;
4. efficient use of Coast Guard resources.

There were two initial strategic drivers for the BACS project. One was the goal to standardize the equipment suite used by VTS San Francisco with the equipment suites being installed at VTS New York and VTS Puget Sound. The other strategic driver originated in Congress. The goal was to free up a portion of the government controlled frequency spectrum for civilian use.

There are other existing strategic drivers, however, that must be researched before all the functional requirements can be addressed. Some of these strategic drivers are being brought on by the Coast Guard streamlining effort. In particular, these drivers include the following:

1. the merging Eleventh District with Pacific Area;
2. the transfer of support functions from district offices to the MLC's;
3. the inception of Activity Commands effecting the command and control structure of groups, Marine Safety Offices (MSO's), air stations, and VTS's. [Ref. 12]

Again, it is imperative we know where we are going, if we are to perform effectively and efficiently.

2. Functional View

Using the functional view, we need to answer the question, "What HQ or unit functional requirements cannot be met without the project?" These requirements are extrapolated from the strategic drivers; however, they will usually come in the form of requests from units, or programs, to change or upgrade functional capabilities. It is important to justify the changes in functional requirements to their strategic drivers. Project proposals which support G-T goals generally get high priority for approval and resources [Ref. 13, p. 21]. This statement could also include Area and Program managers goals, depending on the source, control and availability of resources.

Some of the BACS functional requirements that cannot be met by the existing system include, but are not limited to, the following:

1. the ability to transfer digital data from remote sites to VTC San Francisco;
2. the implementation of new digitally-controlled equipment, including VHF radios, direction finders, and radar processors;

3. rerouting of signals, in the event of a link failure, within the telecommunications system.

3. Physical View

Using the physical view, we need to answer the question, "Is there anything from the physical view that is causing the project?" These could include equipment issues (e.g., lack of replacement parts, reliability, etc.) or maintenance issues (e.g., high maintenance costs, lack of trained maintenance personnel, etc.). In the BACS case, the equipment cannot meet the new functional requirements (i.e., operating outside the 2 GHz frequency spectrum). The equipment also has high maintenance costs and lack of manufacturer support for replacement parts.

E. THE TENTATIVE OPERATIONAL REQUIREMENT (TOR)

The TOR is the initial phase in the formal requirements validation process and is usually submitted by the support/operating program manager when there is a perceived need for a new operational capability. The contents for a TOR are listed in Figure 4. The TOR is analyzed by G-T (or MLCt) branch personnel to verify the requirement, determine if a Development Options Paper (DOP) is required, and provide alternative solutions. The project officer may have to assist the program manager (or requesting command) in writing the TOR. This is an advantage because it gives the AWG an early opportunity to help identify the real needs. If the formal process is not being used --which is likely--then the project officer should develop a "straw" TOR using the same format. When the straw TOR is submitted to the branch chief, it will demonstrate that the project officer has done the homework necessary to identify the true issues. [Ref. 13, p. 23]

The TOR summarizes all the end products of phases I and II. Using the executive guidance provided, the design team will have explained the purpose of the system. By developing the high-level functional requirements, the AWG can envision the desired end-state system and outline an initial plan for achieving this vision. The problem has been bound by using the organizational, functional, and physical views.

FORMAT FOR TENTATIVE OPERATIONAL REQUIREMENT (TOR)

(3-page limit, excluding cover sheet)

I. Cover Sheet. Serves in lieu of forwarding letter.

II. Subject/Title. Provide a short one line subject/title.

III. General Description of Operational Requirement. Describe the type of system needed and its general concept of operations.

IV. Threat. The threat section should either address the threat the system is being designed to counter, the threat environment in which the system must operate, or the threat to the environment that must be resolved.

V. Deficiencies/Shortcoming of Existing Systems. At a minimum classify the deficiency as one of the following:

A. Operational Deficiency - inhibits the performance of a mission or the execution of operational plans.

B. Characteristic Deficiency - inhibits the performance of mission in accordance with doctrinally prescribed characteristics (connectivity, security, speed, reliability, interoperability...etc.)

C. Conceptual Deficiency - deficiency, when corrected can materially improve operations by providing new capabilities; solutions will require significant development.

VI. Range of Capabilities Desired. Outline, in general terms, the key capabilities desired. Include capabilities required versus adverse ocean environment sensitivities. Allow broadest possible range of acceptable performance levels from modest improvement of existing systems to major advances.

VII. General Affordability limits. Provide an estimate (round numbers) of what the resource sponsor is willing to pay (in constant dollars, using current year dollars for: a) RDT&E; b) average unit costs; and c) life-cycle cost (RDT&E, procurement, installation, and five years of operation, all appropriations). This affordability limit serves as a constraint, rather than a fixed limit, for preparing the DOP.

VIII. Facilities/Platform/Quantities. Identify facilities/ships/aircraft, etc. which will employ the system (if applicable), and estimate number to be procured.

IX. Integrated Logistics Support (ILS). Describe any required or limiting logistic planning considerations, including manpower/personnel/training. Provide essential direction regarding the nature of the program required including compliance with or exceptions to key policies and/or procedures.

X. Background/Related Efforts. Discuss interfacing systems, companion developments, etc.. Identification of foreign systems that can reasonably satisfy the range of capabilities specified shall be specifically requested in the TOR.

XI. Program Manager. Clearly identify all program managers, who will be the end user of the system. Also identify any other program managers who will be affected by the acquisition. (i.e., the program managers of all floating platforms or shore stations).

XII. Acquisition Strategy. Summarize overall plan for contracting and procurement, including contract type and incentives.

Figure 4: Tentative Operational Requirement (TOR)

F. CONCLUSION

Phases I and II are the foundation on which any project is founded. If the project officer is not aware of the driving issues behind the decisions made during these phases, the project can quickly get off track. The project officer should not only make a great effort to understand the driving issues, but should be willing, and allowed, to question the issues and decisions made during these phases. The Coast Guard's Command, Control, and Communications ("T") leadership must form and disseminate a well-defined set of strategic objectives for the community.

IV. BASELINE CHARACTERIZATION

A. INTRODUCTION

The baseline characterization is the third process, or phase, in the Structured Approach Model. The purpose of a baseline characterization is to provide the design team a better understanding of the existing system. The baseline characterization must cover both the telecommunications network and the users systems.

A baseline characterization of the existing systems is a critical phase in the process of targeting and developing either a follow-on or new telecommunications network. Without examining the current systems, it is difficult to determine the degree to which the telecommunications network must be upgraded or replaced. Determining the existing systems objectives, processes, and performance permits the design team to target an architecture that best fits the functions and objectives of the enterprise. The enterprise integrates processes and procedures, both manual and automated, for all Coast Guard mission areas and their associated functions. In our analysis, the "enterprise" is comprised of U.S. Coast Guard units in the San Francisco Bay Area that use the BACS.

To better understand the system, the design team will use the baseline characterization to generate a high-level description of the physical aspects of the user systems and existing telecommunications network. The design team will take the mission goals and high-level functional requirements gathered when we "defined the problem," and

break them down into more detailed requirements. These requirements, in turn, will be broken into actual work processes and tasks which must be completed to meet the requirements. Again, we will use the functional, the physical, and the organizational perspectives to accomplish this.

B. ORGANIZATIONAL VIEW

The organizational viewpoint is concerned with the actual working processes used by the enterprise to meet its functional goals. These include working processes which are performed by personnel or by equipment. For example, a functional requirement may state, "Group duty watchstanders shall transmit marine safety notices every four hours simultaneously over the group area of responsibility (AOR)." This requirement would include working processes performed by the watchstander (prepare Notice to Mariners, manually press switch, and speak) and those performed automatically by the equipment and software to enable the signal to transmit over numerous VHF-FM radios concurrently.

When completing a baseline characterization on a complete information system, all work processes performed by the enterprise should be considered. As engineers, we must understand the work processes if we are to design the new information system to be both effective and efficient. Some work processes are effective, but are not efficient. Prior to a telecommunications replacement project is the perfect time for the Coast Guard enterprise to consider re-engineering inefficient work processes. Normally, however, the telecommunications network design team will have very limited resources. Therefore, the scope of this paper is limited to those work processes directly related to

the telecommunications network and the system applications that interface through the network.

1. Determine the Organizational Structure

The definition of organizational structure used here is, "The structure which controls the flow of the work processes." This entails two aspects the design team must keep in mind: 1) the sequential procedures which must be performed to complete the process, and 2) the physical location of resources used to perform the processes. For a simple illustration of how important these two aspects are to understanding the system, we will take another look at the watchstander example. The sequential procedures include switching the console controls to an "all broadcast" position, which in turn initiates software that sends a control signal simultaneously over the telecommunications network to all VHF-FM remote sites. This signal switches the radios to the transmit position. However, the design team must be aware of the locations of the VHF-FM radios if they are going to design a telecommunications network to pass these signals. This example shows where the organizational and physical views converge.

C. Functional View

The functional view addresses the fundamental issue of *what* the system enables the enterprise to accomplish. This has two aspects. The design team must consider 1) each unit's functionality and 2) the role the existing telecommunications system plays in achieving the unit's elemental missions. The functional viewpoint's relationships to the physical and organizational viewpoints must also be considered.

On a superficial level, the BACS provides simple connectivity among the entities comprising the Coast Guard in the Bay Area.

However, a more careful analysis reveals that the BACS provides the enterprise with a wide variety of functionality. These functions can be categorized as both mission area functions and support functions.

Many of the mission area functions derive directly from the legislated responsibilities of the Coast Guard. These mission area applications are those which directly interact with the Coast Guard's external customers. These interactions are manifested in artifacts such as marine safety information, operational unit employment metrics, Broadcast Notices to Mariners, distress messages, and Urgent Marine Information Broadcasts.

However, in this context, mission area functions additionally include those applications required to implement all specific end-user requirements, e.g., personnel management information for internal Coast Guard use.

BACS' support functions include those common applications which are standardized across the various mission areas. These underlying services are available to several mission area functions as needed. In a distributed architecture, these applications would provide such services as electronic mail, text editing, and spreadsheet functionality. They would serve as building blocks which could be called by other applications, remotely, to contribute to their own functionality.

In the BACS case, the services and functionality provided by each layer of the ISO/OSI 7 layer model of telecommunications provides a similar underlying suite of support applications. For example, the transport layer provides error and flow control services across the network to the session layer above it.

In large measure, the functions the BACS performs in support of the Coast Guard are derived from the missions assigned to the Coast Guard itself by the U.S. Congress. Systems designed to meet functional

objectives can have other, dramatic effects. The virtual organizational reengineering that a networking infrastructure such as BACS can implement could help initiate and expand a horizontal integration.

1. Functional Requirements of the Enterprise

a. *Determine the Users' Functional Requirements*

Each unit has their own mission requirements, and therefore their own functional requirements. These requirements are the basis for the system specification.

Gathering and documenting functional requirements is a collaborative effort. The project officer must work with the users, and other CG entities, to fully document these requirements. These include mission sponsors (HQ program offices), support facilities, users within each unit division and chain of command. This collaboration will ensure all the functional requirements are documented and ensure functional requirements have not been misconstrued between the different entities involved. Everyone must be working from the same sheet of music, so to speak.

b. *Rank User Requirements*

The level to which every mission is fulfilled must be limited. Limiting the mission also limits the functionality required. The limiting factor(s) can be cost, technology, time, law, or any number of other factors. Normally, the functional requirements necessary to complete the mission are not spelled out in black and white. Every entity involved with the mission (i.e., mission sponsor, district, unit commander) may have a differing view on what level of functionality is necessary.

For instance, the mission for the Vessel Traffic Service (VTS) is to foster safe travel for vessels of a certain size or type through San

Franciscan waters, as designated by Congress. One level of functionality would be to prevent collisions between participating vessels. Other levels of functional could include preventing collisions between participating vessels and pleasure boats, or between participating vessels and floating logs. These three different levels of functionality require different levels of technical capability. The VTS would like to prevent collisions between ALL participating vessels and pleasure boats and floating logs. This is great for customer satisfaction, as well as job satisfaction. However, the mission sponsor, in this case (G-N), must be willing to foot the bill for the additional technical capability necessary to provide the desired level of functionality.

What must be considered is the incremental differences between meeting the different levels of functionality and whether the unit (or sponsor) is willing to pay those incremental costs. The three different mission requirements mentioned above could be categorized as follows:

- CATEGORY 1: "**must have**" - the functionality required to prevent collisions between participating vessels. This is the functionality which all agree is necessary for mission success.
- CATEGORY 2: "**should have**" - the functionality required to prevent collisions between participating vessels and pleasure boats. This is the functionality which many feel is necessary for political or PR reasons.
- CATEGORY 3: "**nice to have**" - the functionality required to prevent collisions between participating vessels and floating logs. This is the functionality which would make the mission much easier or satisfying, or add to the public's view of the Coast Guard.

Once a unit's functional requirements have been noted, each functional requirement should be placed into one of the three categories. This will help us during the upcoming phases of the structured approach model.

2. Matching Functionality to the Information Systems

At another level of abstraction, however, we can focus on the specific functions the BACS system provides in achieving the unit's elemental missions. This functionality is provided through ten coherent systems. Each is used to gather or disseminate information; therefore, we shall refer to them as information systems. These ten independent information systems can be drawn upon by the enterprise in many varying combinations of functionality.

The information systems that operate over BACS to provide enterprise functionality are outlined in the following ten subsections. Table 1, starting on page 41, contains an inventory of the information systems available at each existing site.

a. *Coast Guard Data Network (CGDN)*

(1) Description

CGDN is the Coast Guard's INTERNET, with access at all stations within the BACS. Each location has a computer terminal which is linked via microwave to either Coast Guard Island or Group San Francisco. These two sites are linked directly into the CONUS-wide WAN, enabling direct contact with all other CG entities. A functional block diagram for the CGDN can be found in Appendix B on page 150.

(2) Functions

1. Electronic mail;
2. Record message traffic (naval messages);

3. Marine Safety Information System updates;
4. Search and Rescue Management Information System updates;
5. Law Enforcement Information System updates;
6. Large Unit Financial System updates.

b. *VHF-FM (Voice) for Vessel Traffic System (VTS) & National Distress System (NDS)*

(1) VTS VHF Description

VTS is a VHF-FM radio system linked on land by microwave, with transmit/receive sites located along the coast. A functional block diagram for the VTS can be found in Appendix B on page 151.

(2) VTS VHF Functions

VTS is a system used by Masters, Pilots, and Commanding Officers piloting commercial and government vessels in the waters subject to the jurisdiction of the Vessel Traffic Scheme (areas in and around San Francisco Bay).

(3) NDS VHF Description

NDS is a system similar to the VTS but broader in scope, with coverage from areas north of San Francisco (around Bodega Bay) to south of Monterey. While Figure 5 contains a simple illustration of the NDS functionality.

(4) NDS VHF Function

The system carries out three completely separate functions:

1. Command and control of Coast Guard cutters, boats, and aircraft in the coastal region;

2. Voice radio interaction with the public;
3. Receipt of reports from mariners in distress.

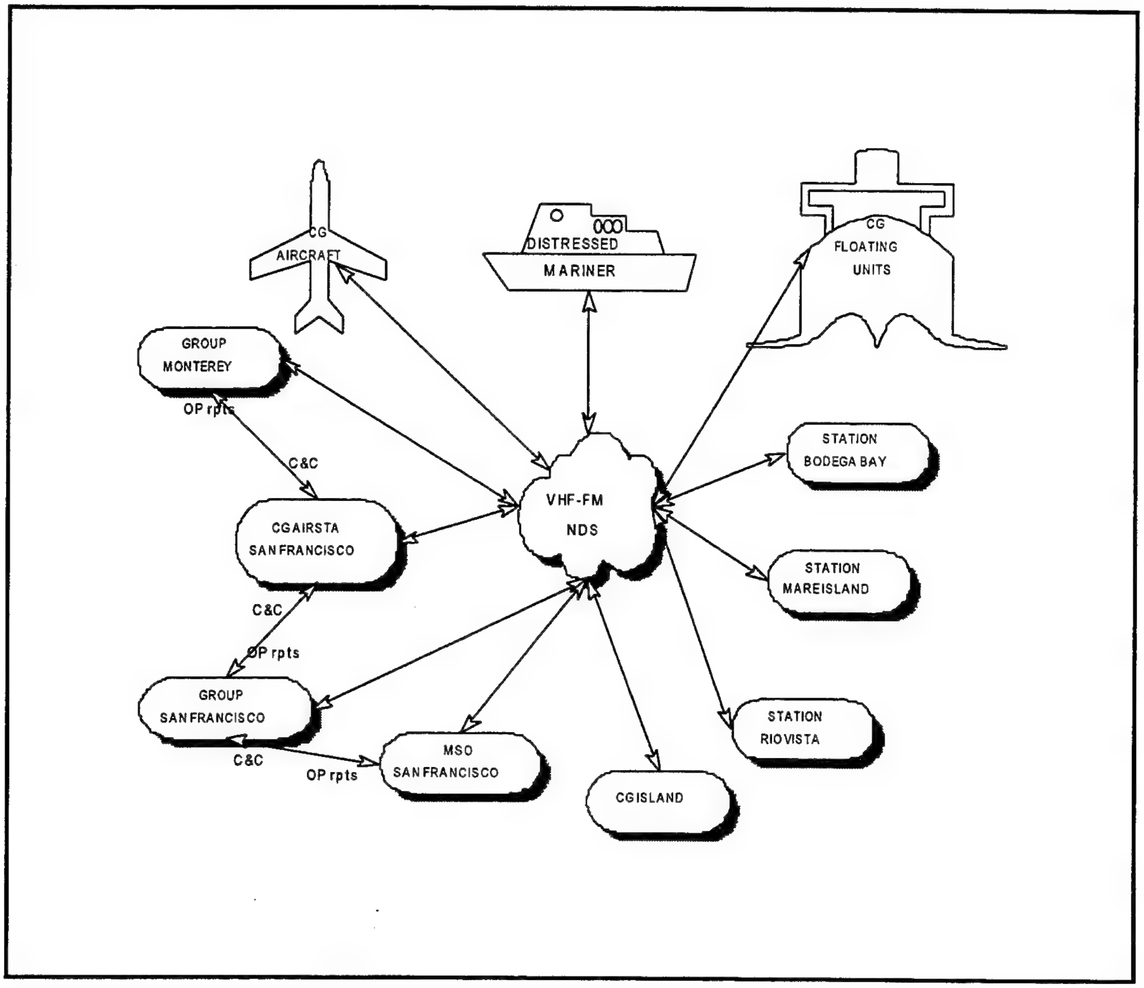


Figure 5: VHF NDS Functionality Illustration

c. *Air Control UHF Voice/Data*

(1) Description

This UHF/Data System connects Air Station San Francisco with Coast Guard Island, and utilizes Mt. Tam as a transmit/receive high site for extended range coverage around the San Francisco Bay Area. A functional block diagram for this system can be found in Appendix B on page 152.

(2) Function

The UHF/Data System enables Air Station San Francisco to exercise longer range command and control and allows Coast Guard Island to monitor the channels.

d. *High Speed Teletype/Data Network (/HDN) and PACINT*

(1) Description

HSTN/HDN is the primary means of teletype (hard copy) message communications for Bay Area Coast Guard units. PACINT is an intelligence support link between COMMSTA San Francisco and PACAREA at Coast Guard Island. A functional block diagram for this system can be found in Appendix B on page 154.

(2) Function

HSTN/HDN supports the PACINT system and all other BACS teletype users for data dissemination for law enforcement and intelligence purposes.

e. *CGI Phone (Telephone PBX System)*

(1) Description

This system is composed of microwave links between various sites, telephone handsets, and a BACS to PBX link located at Coast Guard Island. A functional block diagram for this system can be found in Appendix B on page 155.

(2) Function

Provides telephone service throughout the BACS area, and provides a connection to Public Switched Telephone Network (PSTN) and Federal Telephone System (FTS). The system is used as an in-house

backup for civilian PSTN and FTS and as a maintenance phone for technicians working at BACS microwave sites.

f. *Miscellaneous Systems (HF Radio, Video, Radar, CAMSPAC Link, Alarms)*

(1) Description

All of these systems are composed of similar two-way links from a home site to a remote site, with various functions as described below. A functional block diagram for these systems can be found in Appendix B on page 156.

(2) Functions

The HF radio system provides high frequency voice communications from Group San Francisco to ships at sea, transmitted and received over radio equipment located at Point Bonita. Control signals which operate the equipment are also sent via microwave.

CCTV video signals are transmitted over T-1 lines from four remote sites to the VTS center. The video is used to observe vessel traffic as part of the VTS. Camera control signals are sent via T-1 from the center to the individual cameras to select the desired field of view.

Radar signals are transmitted over T-1 lines from one remote site at Point Bonita to the VTS center. The radar data is used to observe vessel traffic as part of the VTS. Radar control signals are sent via microwave from the center to the radar antennae.

CAMSPAC Link provides a large number of audio, data, and control signals, via microwave, between the transmitting and receiving sites at the Communications Area Master Station.

Alarm signals are transmitted from remote sites, via microwave, to a monitoring station. This system is used in maintaining the status of aids to navigation as part of the Aids Control and

Monitoring System (AMSC). Alarm signals for security and equipment located at the remote sites are also transmitted back to monitoring equipment on CG Island.

Table 1: BACS Information System Inventory

Application Name	Description	Geographic Location(s)	Info Type	Platform Served
CGDN	Coast Guard Data Network	CG Island Communications Area Master Station Pacific (CAMSPAC) Air Station San Francisco Group San Francisco Group Monterey VTS San Francisco Pacific Strike Team Station Rio Vista Station Bodega Bay Station Mare Island Port Security Sta. Concord	Data	Packet Switched Network
VHF-FM NDS	VHF-FM National Distress System	CG Island Group San Francisco Group Monterey Station Mare Island Station Rio Vista Station Bodega Bay Mount Tamalpais Mount Diablo Point Bonita Mount Umunhum Mount Jenner Pigeon Point (landline) Carquenes Heights TV Hill	Audio Control	VHF-FM Radio Operator Console
VTS VHF-FM	Vessel Traffic System VHF-FM Radios	VTS San Francisco Point Bonita Mount Tamalpais TV Hill	Audio Control	VHF-FM Radio Operator Console

Application Name	Description	Geographic Location(s)	Info Type	Platform Served
UHF Air	UHF Air Radio Control	AIRSTA San Francisco Mount Tamalpais	Audio Data	UHF Radio Operator Console
CGI Phone (Telephone PBX)	CG Island Telephone System Remote Access	CAMSPAC San Francisco Pacific Strike Team Group Monterey	Audio	PBX Craft Interface
VTS Radar	VTS Radar Control	Point Bonita VTS San Francisco	Data	Surface Search Radar Operator Console
HF Control	HF Radio Control	Point Bonita Group San Francisco	Audio Control	HF Radio Operator Console
NMC XMIT/RCV Site Link	CAMSPAC Transmit/ Receive Site Link	CAMSPAC San Francisco CAMSPAC Transmit Site CAMSPAC Receive Site	Audio Data Control	HF Radio Operator Console
PACINT	Pacific Area Intelligence Link	Pacific Area (CG Island) CAMSPAC San Francisco	Audio Control	HF Radio Operator Console
AMSC (ALARMS)	Point Bonita Aids To Navigation Control and Monitoring System	Group San Francisco Point Bonita	Data	Alarm System

D. PHYSICAL VIEW

The physical view will outline the physical configuration, coordination, and resources required by the existing system to operate efficiently and effectively. The physical view will be broken into three sections: 1) physical architecture, 2) physical sites, and 3) maintenance. The relationships of the physical viewpoint to the organizational and functional viewpoints are also of concern.

1. Physical Architecture

a. *General Description*

The Bay Area Communications System (BACS) is an analog microwave system which operates in the two gigahertz (GHz) frequency range. BACS links at least eleven Coast Guard units to remote sites using 18 microwave radio links. Each unit is also linked to external networks (e.g., PSTN) through the telephone PBX system located at the communications system's hub on Coast Guard Island.

b. *Existing System Configuration*

Since the entire analog microwave system will be replaced, an in-depth study of the existing system's physical configuration and operating characteristics is unnecessary. However, a list of major components with their descriptions and locations will be necessary during the removal phase.

Of major concern are the existing circuit configurations. A detailed study of each existing circuit must be completed. Information gathered on each circuit should include at least the following:

1. Bandwidth required
2. Signal formats/interoperability requirements

3. Locations of circuit connections
4. Sensitivity to data delays
5. Sensitivity to disruptions in service

This is to ensure the requirements of all existing circuits are considered when choosing and designing the network replacement.

c. *Hardware Components*

Most microwave links have a single antenna at each end. Each link end also has a receiver, transmitter, and "hot standby" transmitter. This "hot standby" transmitter automatically assumes the transmission responsibilities when the main transmitter fails. Two of the BACS microwave links cover long distances over water. The water reflects the signal, causing a second signal to arrive at the receiving antenna shortly after the intended signal. These signal reflections cause multipath reception problems. Additional antennas and a technique known as space diversity are used at each end of these links to overcome the multipath reception problems. This approach enables the system to function effectively despite the long over-water paths required.

2. Evaluating the Existing System Baseline

An evaluation of the existing network must be completed. A "list of network deficiencies" should be compiled and include items such as links with high-fade margin rates, and required services not provided by the existing system. A "list of opportunities" should be collected and include items such as excess circuits and circuits that can be combined or deleted entirely.

a. *Measures of Performance*

Measures of performance (MOP) can be used to indicate whether or not a network meets the functional or technical requirements

it was intended to satisfy. The Coast Guard has not been using any MOP to track the microwave network's overall performance. No records of network failure, calibration, or component replacement have been generated.

However, there are four communications-oriented measures of performance used by the Coast Guard to ensure the communications links between sites remain within nominal specifications:

1. Fade Margin - Measures signal attenuation across a microwave link
2. Receiver Signal Level - Measures carrier signal power level
3. Baseband Level - Measures the incoming Baseband signal strength
4. Idle Channel Noise Level - Measures the amount of noise created by the microwave system itself.

Since any alternative supporting system would likely be based on a different technology, additional development of MOP for the existing network would not be beneficial.

3. Physical Sites

a. *Types of Sites*

There are four fundamentally different types of physical locations (sites): "mega-station" (Group San Francisco and Coast Guard Island), "station," "relay high site," and "navaid/end site." Their descriptions are as follows:

1. The "mega-station" category includes both Group San Francisco and Coast Guard Island, the two primary communications hubs that support the command and control structure for this region of California. The two sites contain all or most of the communications systems previously described above in Section B, Functional Architecture. A drawing showing a consolidated version of the two sites can be found in Appendix B on page 156.

2. A "station" includes sites such as Group Monterey, Bodega Bay, and Air Station San Francisco. These sites are primarily at the operational level, and control specific missions within their respective areas of responsibility. "Station" sites either control or receive information from "navaid/end sites" directly or via "relay high sites." A drawing showing a generic version of a "station" can be found in Appendix B on page 157.

3. "Relay high sites" are located on topographically high locations throughout the BACS area, and provide the line-of-sight necessary for the microwave communication links, and good transmit/receive locations for the UHF/VHF radios. These sites connect from two to six microwave links together. A drawing showing a generic version of a "relay high site" can be found in Appendix B on page 158.

4. "Navaid/end sites" are primarily remote sensor (radar, television monitor, radio antenna) or navaid sites (light house). Control signals for these remote sites are received via microwave or T-1 lines, and the sensed data is returned to the controlling station via similar means. A drawing showing a generic version of a "navaid/end site" can be found in Appendix B on page 159.

b. *Site Configuration*

Each site must be visited and an evaluation of its physical limitations such as space, power, "heating, ventilation, & air conditioning" (HVAC), remoteness, tower limits, etc., must be completed. A table, such as that in Table 2, can be developed to assist the project officer in documenting the sites physical limitations. This table will be essential when selecting alternative technologies and equipment for each site.

Table 2: Site Configuration Table

	ASFO	**BYPT**	. . .	**YBIS**
Floor Space Avail (Ft)	10 x 4	10 x 4	. . .	6 x 4
Blkhd Space Avail (H x W)	6 x 5 + 2 x 8	6 x 4 + 3 x 8	. . .	8 x 4 + 2 x 2
A/C Circuitbreakers Avail	3 (20a) + 1 (50a)	3 (20a) + 1 (50a)	. . .	6 (20a) + 2 (50a)
Rack Space Avail (H X W)	36 x 27	48 x 27	. . .	72 x 27
UPS Power Avail	Approx. 15a	Approx. 20a	. . .	None
. . .	. . .	. . .	. . .	. . .
Tower Weight Limit			. . .	

c. *Maintenance*

Network maintenance is performed to prevent or limit loss of communications, and repair the network after failure. The maintenance

resources required for the new network will normally differ from those of the existing network. However, a baseline of resources used to maintain the existing network is essential for planning. The project officer can use this baseline to:

1. compute the estimated costs associated with maintaining the existing network;
2. estimate the resources required for the replacement network;
3. estimate maintenance costs for the replacement network;
4. plan changes to the existing maintenance structure (including contracts, billets, ordering procedures, etc.).

Since maintenance resources used for the telecommunications network may also be used for other purposes, the maintenance resources must be broken down to a level low enough to make these overlapping uses apparent.

CG telecommunications networks can use both CG and contract resources. Quarterly and annual preventive maintenance is performed by Coast Guard Telephone Technicians assigned to the Telephone Technician Shop on Coast Guard Island. Preventive maintenance for BACS is both costly and very time consuming. Technicians are required to be at both ends of any analog microwave link when the network is being adjusted. This adds greatly to the amount of travel time required. Unlike a digital network, an analog network does not remove noise at each relay site by regenerating the original signal. Therefore, the network must frequently be fine-tuned to reduce noise interference.

Emergency maintenance is performed by the Coast Guard technicians when a link fails. Although no maintenance records have been kept, technicians indicate that approximately 1-2 failures occurs

each year. The link is normally restored within 3-4 hours, but, a link has been inoperative for as long as three days.

The project officer must also consider maintenance to the building structures and surrounding grounds. At times, this maintenance is more difficult to arrange than network maintenance.

d. *Overall Assessment*

Without regard to the costs of operating and maintaining the network, BACS has satisfied the original requirements of a privately-owned communications network. When evaluating the cost side of a cost/effectiveness assessment, however, the continued use of BACS is questionable.

The network incurs explicit costs in a number of areas, including:

1. Salaried maintenance technicians continuously on call;
2. Electric power consumption;
3. Recurring hardware replacement;
4. Recurring preventive maintenance.

Implicit costs of the network are more problematic. The most significant of these is caused by BACS being firmly entrenched in an obsolete technology: the analog microwave network provides no migration path to high speed digital technology. The opportunity costs associated with the limitations of this infrastructure are severe.

The most immediate shortcoming exists in the lack of significant broadband digital connectivity between 1) the Commander, Pacific Area's headquarters in Alameda, and CAMSPAC; and 2) the VTC and remote radar sites. This shortcoming immediately prohibits the implementation of the Coast Guard's goal to eliminate all dedicated

communications personnel at the Alameda Command Center and headquarters.

While a concrete capacity figure is not forthcoming from the users, the existing technology clearly does not support the present vision of the organization.

Reliance on non-secure command and control links via the VHF-FM system prevents the organization from achieving it is command and control requirements under it is national defense tasking. Limitations of the existing network again prevent the organization from migrating to communication and encryption systems compatible with the DOD.

E. CONCLUSION

The baseline characterization is essential to understanding where we are going and how we will get there. A well documented baseline characterization can prevent the design team from overlooking many of the smaller details that turn into major problems as the project moves forward. By using the Structured Approach Model, a project officer will ensure all aspects of the baseline characterization have been considered.

Opportunities for reengineering are clear. Feasible target architectures should be explored. A target architecture should be chosen which best matches the anticipated future requirements, expected technology maturation, and realistic funding levels achievable. A cost/effectiveness analysis must be conducted to support the procurement decision. A privately owned microwave network is only one of several possible alternatives to meet the future requirements presently served by BACS.

V. TARGET ARCHITECTURE

A. INTRODUCTION

"Determine Target Architecture" is the fourth process of the Structured Approach Model. Recall that the design team must determine target architecture for each of the users systems before a network target architecture can be considered. The purpose of the Target Architecture process is to outline the technical capabilities the final network configuration must possess to meet the user requirements.

The new architecture need not be developed based on cost-effective or "business case-based" criteria. The real world constraints of cost/effectiveness analysis and cost justification will be introduced in the "Select Migration Path" phase of the Structured Approach Process.

At this phase in the process, it is desirable to define a target architecture that can be used to achieve the vision of the organization from all three views. Ultimately, constraints will come to bear on the funding of each project that is needed to achieve the target; but, for now, it is sufficient to flesh out the target to identify the full spectrum of what is needed to achieve the vision of the organization [Ref. , p. 4-3].

Sometimes an organization cannot implement the target architecture without either disrupting the quality of service provided to the enterprise or expending an excessive amount of resources to get there. Therefore, it is important that the design team take the time to outline a set of alternative architectures that may become an interim target until the ultimate target can be legitimately reached.

There are four conceptual levels of architecture that should be discussed; these are shown in Figure 6. The "baseline" is the

architecture that already exists; the "migration path" could contain a number of configurations to be implemented over time to reach the final target (the first of these is known as the "base system"); the "modified target architecture" is the future architecture we may have to settle for due to system or cost constraints; and the "ultimate target architecture" is where we finally want to get.

This section describes the overall process by which the architecture framework is extended by the design team. The issues for the design team to be concerned with during this process include:

1. An extension of the vision as described in the "Organize and Plan" process;
2. A description of the future enterprise and a desired future architecture required to meet future functional requirements;
3. An identification of what can be extended from the current environment into the target environment.

But what can the design team do if no vision exists for a future architecture? This can be either a blessing or a curse, depending upon

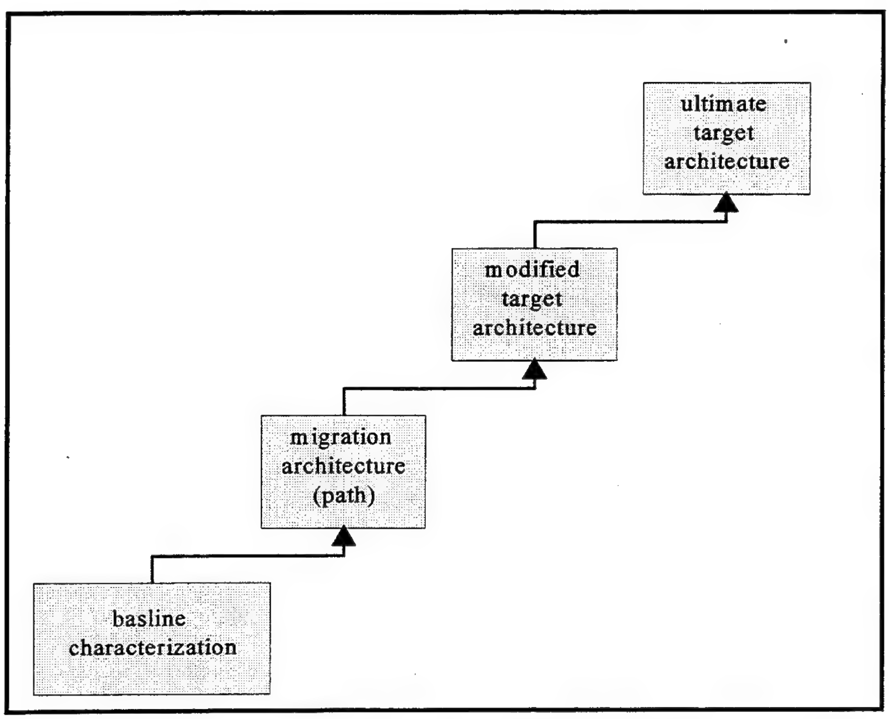


Figure 6: Four Levels of System Architecture

how much effort the design team (and the enterprise) is willing to put forth on the project. It is much like an artist being given a blank canvas and told to paint the future. If the artist expends some effort in research, he can get very close to the near future. Like the artist, if the design team does its research, they can target an architecture that will normally meet the enterprise's future needs But, without the research, it is just a stab in the dark.

Now, we will take a look at some procedures the design team can use to design the target architecture. Here again, the three views have been used to ensure all perspectives are considered. Figure 7 depicts an overall framework the design team can use while developing the target architecture. As we saw in the earlier phases, each view of the target architecture has some overlap with aspects of the other views (see Figure 8, Figure 9, and Figure 11, below). This overlap supports the argument that we are developing a single, integrated architecture [Ref. 8, p. 4-4]. The design team can frequently refer to this meta-model in order to remain focused on the key aspects of the task at hand.

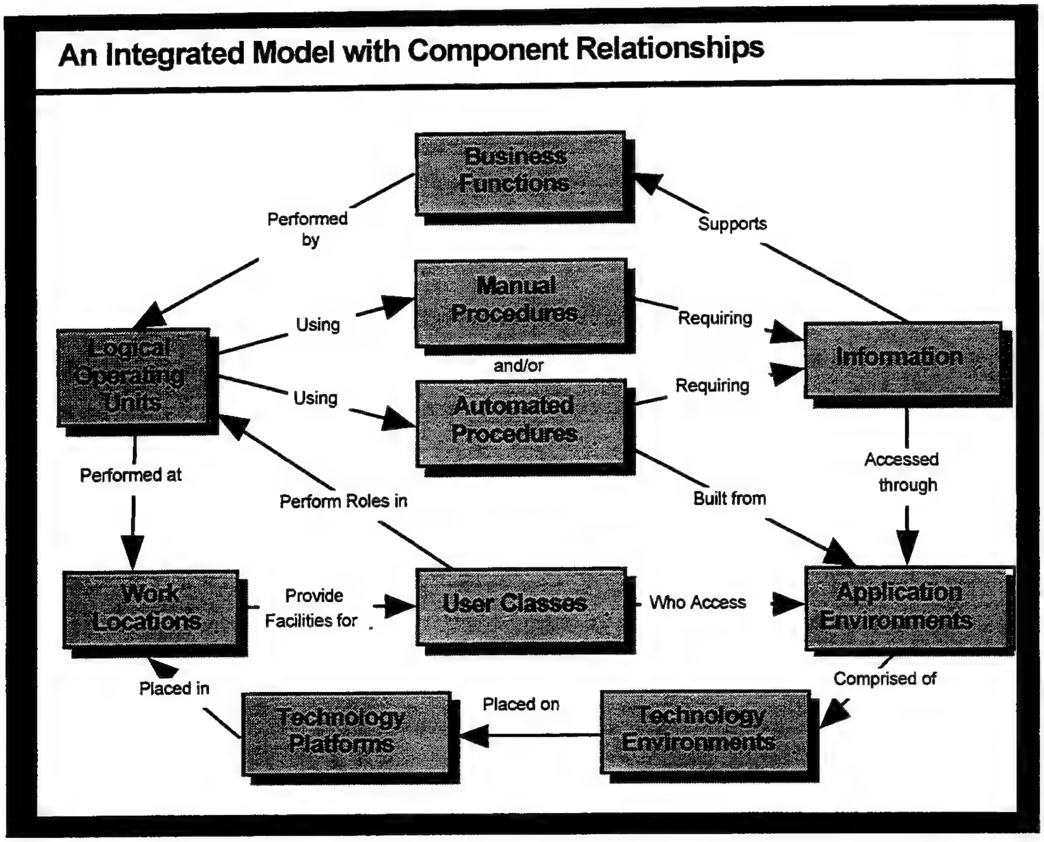


Figure 7: Integrated Model with Component Relationships (TAFIM Vol. 4)

B. ORGANIZATIONAL VIEW

1. Changes to the Existing Organizational Structure

The organizational structure can be looked at in two different context. One is from the task prospective. This includes the enterprise tasking and the information flow required to perform the functional requirements. The other context is from the enterprise unit, or command, structure. Figure 8 highlights those areas that the design team should keep in mind while concentrating on the organizational view.

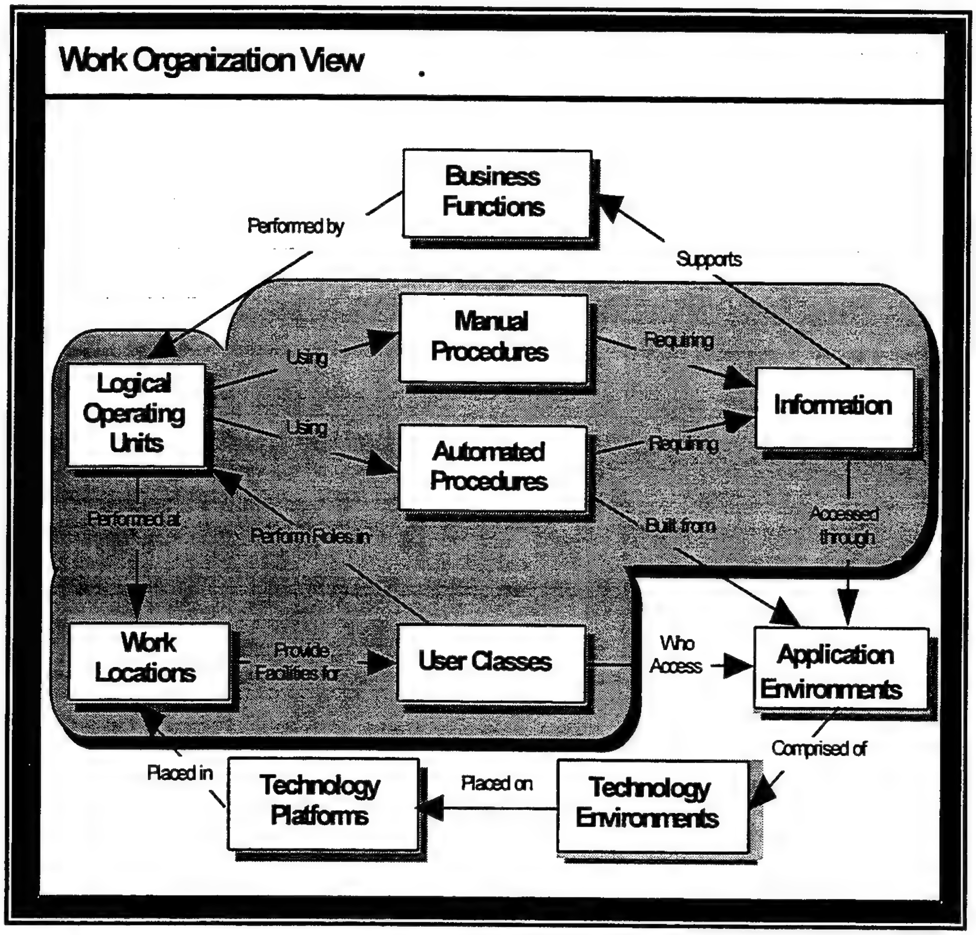


Figure 8: Integrated Model Highlighting Organizational View

When evaluating the users systems, the tasking should be studied in great detail and changes recommended where appropriate. This

should be done with complete disregard for the unit structure. [Ref. 8] For example, suppose we are designing a new centralized information system for tracking cargo and shipping data for U.S. ports. The data is normally supplied to Coast Guard Headquarters' (CGHQ) from the VTS in the form of quarterly reports; they, in turn, have gathered the information from the port authorities. Looking at it from the unit structure context, we might electronically collect the information from the VTS. Looking at it from the tasking context, we see that it would be more efficient to electronically collect the information directly from the port authorities.

Although the design team may have very little input into task reassignment, it should still take a broad look at the tasking necessary to perform existing and anticipated future functional requirements and make recommendations for change where necessary. In this manner, the command structure will have the option to reengineer the tasking before the new system is put in place.

2. Determine Other Potential Network Users

Depending on the location and the type of telecommunications network implemented, other government entities may have telecommunication requirements that can be accommodated on a CG owned network. Although, at this point the type of network to be installed will not be known, the design team should keep this in mind when visiting the enterprise sites. They should inquire into any other government interests that are located near the sites. Other government entities would be responsible for providing their signals to demarcation points located at the necessary sites. They can also be required to share in the costs of the network. Since participation by outside agencies

could affect the target architecture to be chosen, these agencies should be contacted as early as possible.

C. FUNCTIONAL VIEW

To reiterate, functional requirements are those functions which must be completed by the enterprise for their mission(s) to be a success. We have already researched the existing functional requirements during the basic characterization phase. Now, the design team must determine what new functional requirements may be added in the future. While the Coast Guard's missions and functional requirements for seven to ten years from now are not documented, there are signs which point to the direction in that we are heading. Many of these signs are now being posted by our leaders in the Congress, the Coast Guard, and the rest of government.

Each of the program offices in CGHQ have assigned planning staffs. They possibly have already gathered information from government sources, industry, national and international committees and combined it with their own plans for the future. Their plans control the future of the network users. Therefore, the knowledge contained within their plans must be captured and incorporated by the design team.

It is up to the project officer and his command to determine what method is used to gather this information. One method would be to hold face-to-face meetings with the subject experts. This is the easiest way for many people to brainstorm and participate in true dialogue. However, I would recommend that before any meetings are held, the project officer's command send a formal letter to spell out the purpose, the plan, and request an individual be assigned to work with the design team. This will allow each office to properly assign the task and begin the necessary research. This may seem like an inordinate amount of work, but proper

planning pays off. Once this information is obtained, meetings can be held to assess the impact on the enterprise's organization and mission requirements, and negotiate the level of functional implementation.

By assessing the likelihood of major changes to the Coast Guard, and therefore the functions and missions, we can better analyze the risks of different target architectures. For instance, one alternative may meet today's requirements, but not be adaptable to future technology. Another alternative may provide more versatility for the future, but at a higher cost. This assessment of functional and mission change should lead to a number of different scenarios, each with its own set of missions and functional requirements. These scenarios should be deeply deliberated on by the design team to ensure the target architecture chosen will have the highest probability of meeting the enterprises future requirements. Figure 9 highlights those areas that the design team should concentrate on while researching the functional view.

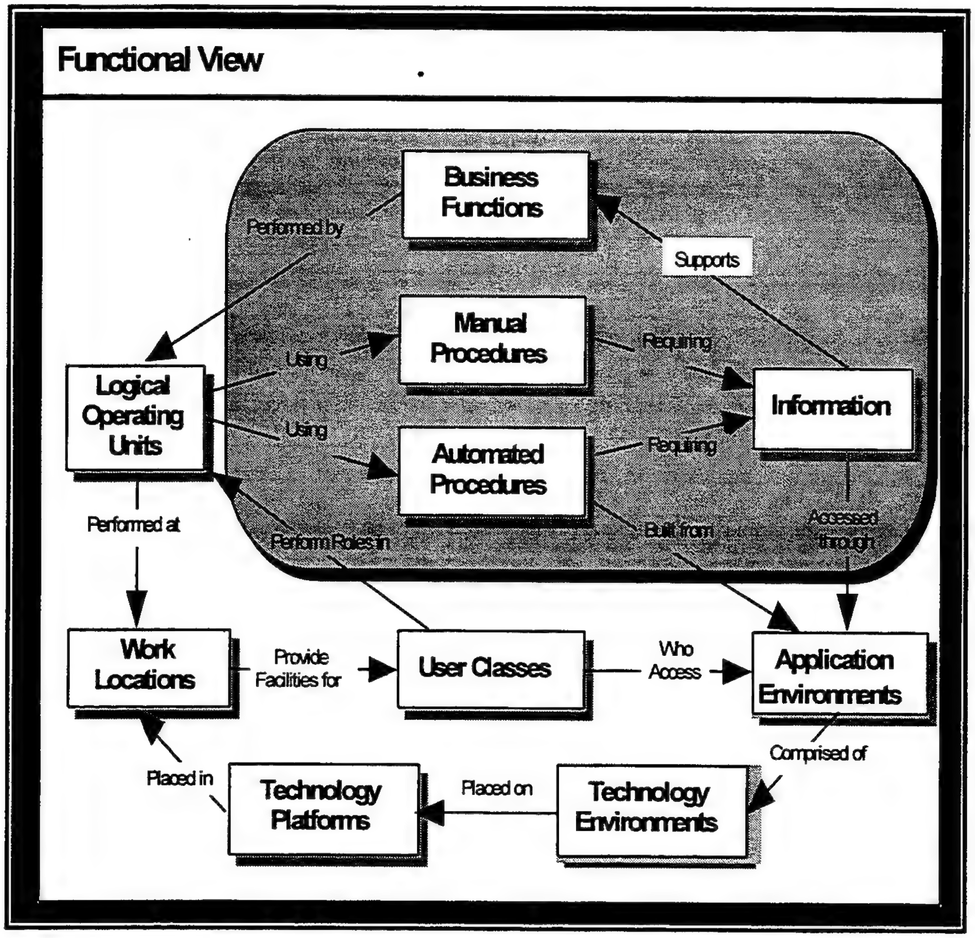


Figure 9: Integrated Model Highlighting Functional View

The functional requirements of the existing missions must be met by the *base system* (1st migration configuration). For each scenario, the future functional requirements of each unit should be compared to the existing functional requirements. If they are the same, or have diminished, they may be disregarded. If different, they should be properly labeled and added to the list of functional requirements.

We now have a completed list of functional requirements which include those from the baseline characterization and the additional functional requirements considered for the future. It is now time for another round of dialogue and negotiation between the entities having a stake in the project. This group must categorize the requirements into one of the three categories, "Must Have," "Should Have," or "Nice to

Have." Here again, dialogue and negotiation are the keys to developing an acceptable plan. This category information will be used to develop relative values for the functional requirements during the following phases.

A date indicating the year that a functional requirement will be required should be attached to each requirement. The configuration shown in Figure 10 will be used here to represent each functional requirement. This notation will be very useful during the follow-on phases.

$$Fn_{a:b}$$

F: the function

n: the assigned function number

a: the category the function is assigned to (i. e., 1, 2, 3)

b: the year the function is required

Figure 10: Symbol Configuration Representing Functional Requirements

Determining the final categories for each requirement, and the date each is required, will take a considerable amount of dialogue and negotiation. The project officer must facilitate this dialogue between the program managers, the commands, and the different levels of users. His role is critical if the final systems are to be the most efficient and effective available. The final categories and dates for each functional requirement may depend upon the results of the cost/effectiveness analysis performed in the next phase. Another round of negotiations may be necessary at that time. But for now we will assume they will not change.

D. PHYSICAL VIEW

The areas the design team should be concerned with while

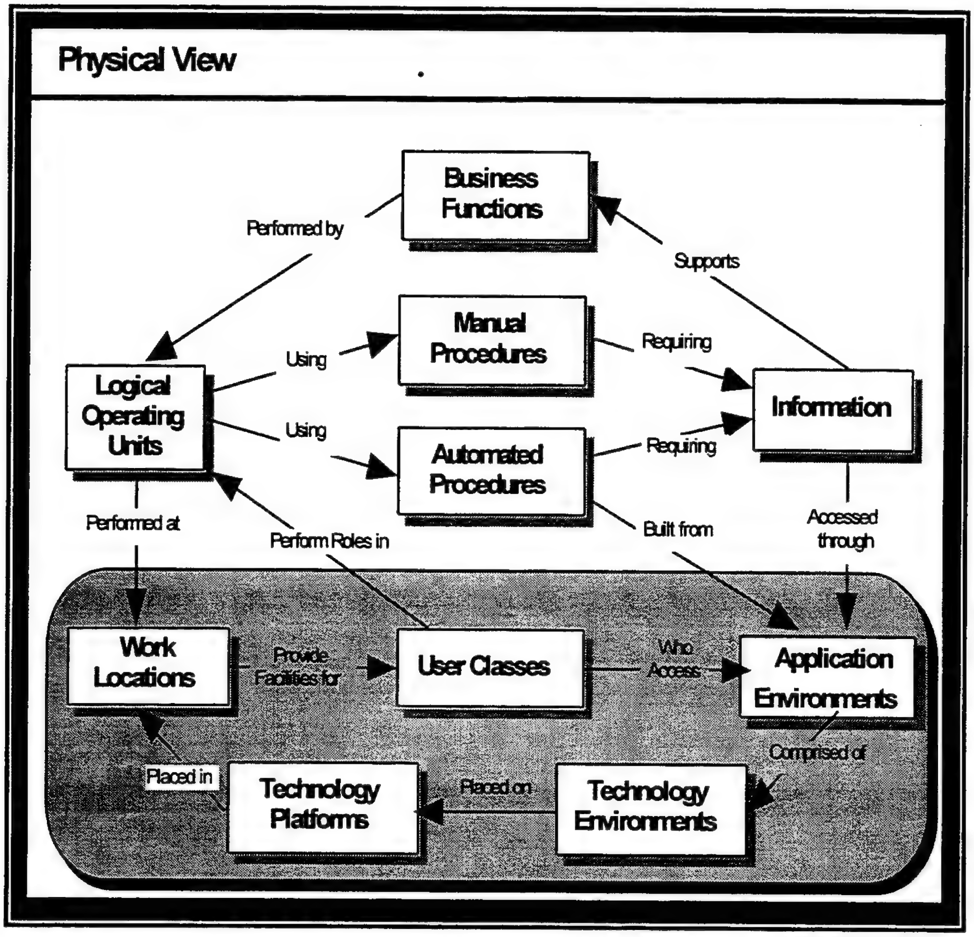


Figure 11: Integrated Model Highlighting the Physical View

concentrating on the physical view are highlighted in Figure 11. While developing the target architecture's physical view, what is important is the underlying architecture, not particular equipment suites or software bundles. To define the target architecture, TAFIM uses the terms Generic Application Environments (GAE), Generic Technology

Environments (GTE), and Generic Technology Platforms (GTP).[1] The six GTP's and examples of GAE's and GTE's can be found in Table 3.[2]

In the absence of promulgated standards, the design team must choose the standards to be incorporated. To implement a standards-based infrastructure, it is important to consider the scope and depth of the standards to be adopted. Fundamentally, all cases of standards adoption require answering three questions:

1. What standards should we adopt?
2. Where in our architecture should we adopt them?
3. When should we adopt them?

Standards should be selected for the users systems, as well as the telecommunications network. TAFIM, Volume 2, should be used in this phase. It suggests a standards-based model with sections for user interface, database, applications, operating system, communications, languages, management, and other services. The design team must be prepared to define the details that underpin each of the above sections of the model required for project implementation. TAFIM, Volume 4, Appendix C, can also be a good reference point for teams attempting to define the details of the standards model. [Ref. 8, p. 4-28]

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[1] TAFIM, Vol. 4, Appendix D contains complete definitions for these terms.

[2] An abbreviated definition for each of the GAE's, GTE's, and GTP's listed can be found in the Glossary.

Table 3: Examples of GAE, GTE, & the Six GTP

GAE	GTE	GTP
Batch processing	User interface services	Intelligent Wide Area Network Systems
Transaction processing	System management services	Establishment-based Switching Systems
Inquiry processing	Communications management services	Local Area Network Systems
Decision support	Database management services	Enterprise or Corporate Processing Systems
Expert systems	Hypermedia	Divisional or Departmental Processing Systems
Real-time control	Transaction media services	Desktop or Portable Intelligent Workstations
Text processing	Document management services	
Document processing	Conferencing management services	
Electronic publishing	Distribution services	
Hypermedia processing	Repository services	
Video processing	Repositories for system construction	
Document storage & retrieval	Repositories for systems management	
Electronic mail	Server definitions	
Voice mail	Name server	
Enhanced telephony	Authentication server	
Shared screen teleconferencing	Access control server	
Video teleconferencing	Cryptographic server	
Broadcast	Communications server	
Computer conferencing	Time server	
	File server	
	Data server	
	Print server	
	Mail server	
	EDI translation server	
	Applications server	
	Presentation server	
	Sensor monitor/actuator server	

1. Requirements VS. Technical Capabilities VS. Sites

Once the functional requirements for the users systems have been determined, they must be matched to the technical capabilities necessary to provide them. A matrix of Functional Requirements/Technical Capabilities should be developed. An example of such a matrix can be seen in Table 4. An "X" placed in the column of a requirement and the row of a technical capability signifies that the technical capability must be provided if the functional requirement is to be met.

Functional Requirement (Fn)/Technical Capability (TC) Table										
	Functional Requirements ($Fn_{cat.:\,year\ required}$)									
	$F1_{2:96}$	$F2_{3:95}$	$F3_{3:96}$	$F4_{1:95}$	$F5_{1:98}$	$F6_{2:95}$	$F7_{2:95}$	$F8_{1:98}$	..	$Fn_{3:96}$
TC1	X	X			X				..	
TC2			X		X	X	X		..	X
TC3	X			X	X				..	X
TC4	X	X				X		X	..	X
TC5				X		X			..	
...	...	...	...	...	...	...	...	...	..	...
TCn			X		X			X	..	

Table 4: Functional Requirements/Technical Capabilities Matrix

At the same time, a matrix depicting the relationship of technical capabilities and enterprise sites should be constructed. A suggested symbol configuration can be seen in Figure 12. With this configuration, we can tell at a glance what category of functionality has been called for and what is the earliest year for implementation.

$$TCn_{a:b-c}$$

TC: technical capability designator

n: the assigned TC number

a: the highest functionality category of the TC (i.e., 1, 2, 3)

b: the earliest year the TC is required; for the highest level of functionality

c: the earliest year the TC is required for lower level of functionality (if earlier than b)

Figure 12: Symbol Configuration Representing Technical Capability

Table 5 illustrates the Site/Technical Capability Matrix. The technical capabilities inherit their functionality categories and implementation year designators from the functional requirements with the highest assigned functionality category they correlate to. If the date

Site (S)/Technical Capability (TC) table										
	Site									
($TCn_{cat.:\ year\ required}$)	S1	S2	S3	S4	S5	S6	S7	S8	..	Sn
$TC1_{1:95}$	95	95			95				..	
$TC2_{1:98-95}$			98		98	95	96		..	97
$TC3_{1:95}$	95			95	95				..	95
$TC4_{1:98-95}$	98	98				95		98	..	97
$TC5_{1:95}$				95		95			..	
...	...	...	...	...	...	...	...	...	..	...
$TCn_{1:98-96}$			98		98			98	..	

Table 5: Site/Technical Capability Matrix

of a lower category is earlier than the higher category, a second year designator is added to the symbol.

For example, TC2 has a category one requirement for "98," but it also has a category two date for "95." Therefore, the complete symbol would be "$TC2_{1:98-95}$." Note that if the functionality is category one, the date can only be moved earlier; if it is category two or three, the implementation date is negotiable either earlier or later. Instead of filling the correlation box with an "X," the box is marked with the date chosen for implementing that technical capability at that particular site. These dates can be changed in order to come up with the most cost-efficient implementation schedule (depending upon functionality requirements and network implementation.

The purpose for these matrices is to help the design team, users, and reviewers track the required functionality and technology in a systematic manner. It simplifies the process of documenting which functional requirements drive which technical capabilities and at what sites the technical capabilities are required. It will assist in tracking how many equipment suites must be planned for and how much space will be necessary at each particular site.

Once the above process has been completed for the users systems, the same type of matrices should be constructed for the telecommunications network. These will be very useful to all those who participate in the functional/technical dialogue and assist the design team while dealing with system migration during the next two phases.

E. THE BACS TARGET ARCHITECTURE

1. Organizational

With the new CG streamlining measures coming into effect [Ref. 12], the BACS design team has it is job cut out. Many of the missions, functions, and workflows for a number of the BACS user commands will be affected (i.e., growth of MLCP, dismantling of D11, new PACAREA responsibilities, etc.).

Because the streamlining measures are causing changes in the "system," the BACS project has actually come at an opportune moment. As we discussed in chapter one, one biggest stumbling block to implementing change is overcoming the resistance. In this case, the "system" is already facing mandatory change. With the investment of some resources, PACAREA and MLCP have the perfect opportunity to re-engineer some of the more ineffective or inefficient workflows. This could lead to much greater savings in the future.

Even if the command structure does not take advantage of this opportunity, the design team must still re-evaluate the telecommunication needs for each of these units. This is critical if they are to design a network capable of serving this newly organized enterprise, today, and into the future.

There is the possibility the BACS network could be used by other government agencies. Many of the remote sites are located next to equipment owned by the Navy, Forest Service, Federal Aviation Administration, and others. These agencies should be spoken with before the project gets too far into the planning stage.

2. Functional

The BACS network is a very large, complex project. The required functionality of the different user commands covers the scale from one

end to the other. Due to this size and complexity, the project officer should implement a procedure, like the procedures suggested above, to track and document the project.

The opinions on the required level of functionality vary in the same way. Because the political level of functionality is above that of the project officer, he must assume the role of facilitator. He must encourage dialogue and lead the entities involved to a consensus. The group must be willing to explore new possibilities and work together for the good of the whole enterprise.

3. Physical

With all the recent changes in the telecommunications industry, we must be careful not to lock ourselves into a given technology or way of doing business because "that is the way it is always been done." If this occurs, we will be limiting our opportunities to take advantage of the before-mentioned advances.

F. CONCLUSION

By using the Structured Approach Model, we have systematically completed the following:

1. We have considered the CG-wide visions and strategy for which our project can help, or hinder, implementation.
2. We have defined the problem by listing the visions and operational requirements which cannot be met by the system along with any existing limitations or discrepancies with the physical structure which justify replacement.
3. We have drawn a limited picture of "where we are" with respect to user systems by inventorying the physical sites and resources, studying work-flow patterns, and collecting user requirements. We have drawn the same kind of picture for the existing telecommunications network by inventorying the sites and resources, studying the existing circuits and network management techniques.

4. We have determined “where we want to go” by attempting to collect future requirements, by considering possible changes to organizational structure and business processes, and by determining a standards-based system architecture that can meet the functional requirements independent of a specific technology implementation. We have also developed a matrix that correlates the functional requirements with the technical capabilities required to implement them and a matrix that correlates the technical capabilities to the sites (correlates technical capabilities for both the user systems and the telecommunications network).

VI. GENERAL COMMUNICATION SERVICES & TECHNOLOGIES

A. INTRODUCTION

The purpose of this chapter is to review some of the basic communication services, protocols, and technologies available today. To complete the target architecture, the design team must have an understanding for the technology that is available today and where technology is headed tomorrow. They should possess a working level understanding of the existing de jure standards and the architectures which form their foundations.

This chapter provides a broad discussion of basic communications engineering concerns and some of the more prevalent architecture standards and transmission media available today.

The block diagram of a general communication system is given in Figure 13. The basic problem faced when designing a communication system can be viewed from two different aspects. These two views include designing a communications system that:

1. Uses a given transmission channel as effectively as possible. This means that the channel should convey the maximum possible amount of information in the time permitted, consistent with the noise introduced and the error in the received message that can be tolerated [Ref. 14]. This view deals with *channel effectiveness.*

2. Provides the most economical channel to use with the given message, consistent with the noise sources and the allowable error rate. The choice of the method of coding, as well as the design of all the components in the coder, channel, and decoder, must be considered to overcome these limitations. This view deals with *channel efficiency.*

In this diagram we can introduce either a wired or wireless system in the transmission channel as a means of transmission interconnection. Telephone lines are an example of a wired interconnection, while cellular, microwave, and satellite systems are examples of wireless systems.

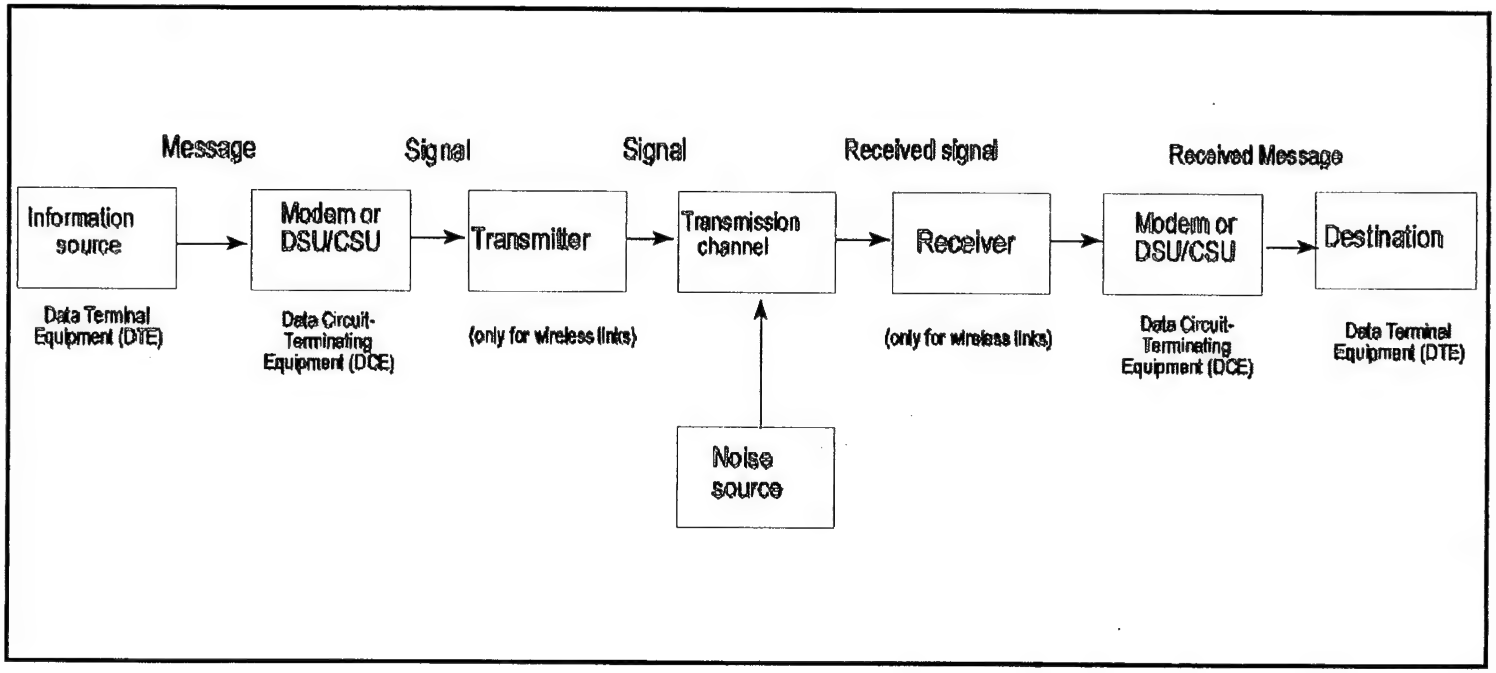

Figure 13: Schematic of a General Communication System

B. THE BASICS OF COMMUNICATIONS

In any communication system information to be transmitted is generally available in the form of an electrical signal that may take one of two forms: an analog or a digital signal. In the analog case, the signal (e.g., electric current) varies continuously with time, as shown schematically in Figure 14(a). In the case of a digital signal, the signal will normally have one of two (and sometimes three) voltage values. These values represent the digital bits "0" and "1" (bit stands for binary digit), as shown schematically in Figure 14(b).

An analog signal can be converted into digital form by sampling it at regular intervals of time. Communications by digital signaling is an increasingly important technique for radio communications. With the exception of slow (below 56 Kbps) dial-up circuits using modems, most WAN connections use digital transmission. Therefore, this discussion

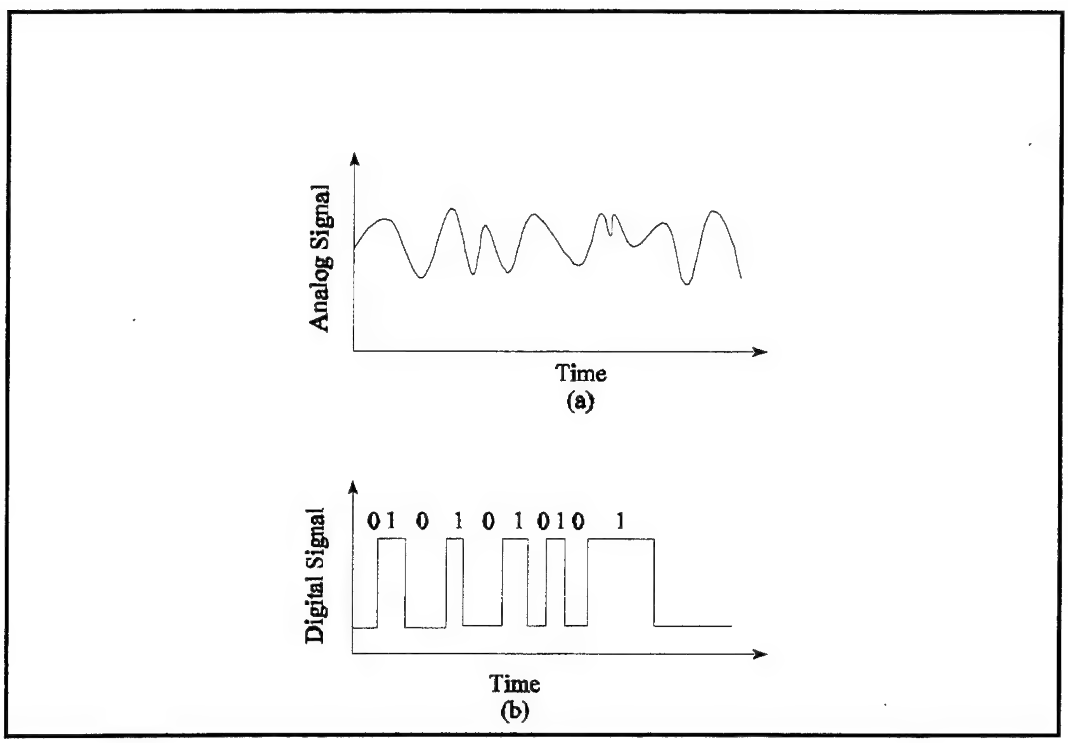

Figure 14: Representation of a) an Analog Signal & b) a Digital Signal

will focus on digital transmission techniques.

Digital transmission has a number of advantages over other techniques [Ref. 15]. These include :

1. the ease and efficiency of multiplexing multiple signals or handling digital messages in "packets" for convenient switching;
2. the relative insensitivity of digital circuits to re-transmission noise, commonly a problem with analog systems;
3. potential for extremely low error rates and high fidelity through error detection and correction;
4. communications privacy;
5. the flexibility of digital hardware implementation, which permits the use of microprocessor, digital switching, and the use of large-scale integrated circuits.

Digital transmission techniques require an analog-to-digital interface (or vice-versa) when the original form of the information transmitted is analog.

There are three basics required for data communications [Ref. 16]:

1. a physical connection;
2. a set of data communication functions performed by participating computers;
3. use of common protocol for each communication function.

1. Physical Connection

Physical connections can be provided over many types of transmission media (e.g., twisted pair, coax, microwave). Connections are made either over a dedicated link or through a switched network. Types of networks will be discussed further in section b4-b7.

2. Communication Functions

The following are communication functions which must be performed by participating network computers:

1. information encoding;
2. encryption/compression;
3. session management;
4. error and flow control - from originating point, across network(s), to destination [3];
5. interaction with network;
6. error and flow control - across each link between nodes;
7. bit encoding.

Due to the complexity of implementing the above functions, standard data communication architectures have been developed to decompose these functions into more manageable modules and define interaction between the modules. The four standard architectures include:

1. IBM's System Network Architecture (SNA) - proprietary;
2. DEC's Digital Network Architecture (DNA) - proprietary;
3. ISO' Open Systems Interconnection (OSI) - open standard;
4. DOD's TCP/IP Architecture - open standard.

This discussion will focus on the open standard network architectures (i.e., OSI, TCP/IP) since these are the standards used widely by the U. S. government.

[3] These are unnecessary for dedicated connections.

Each of the communication functions mentioned above are contained within one of the layers of each architecture. This can be seen in Table 6. Each architecture layer uses protocols to specify how the functionality is to be provided.

Table 6: Association of Communication Functions with Architecture Layers

OSI Architecture	Communication Function	DOD's TCP/IP Architecture
Layer 7: Application	Information Encoding (specific applications; such as Email, File Transfer, etc.)	Layer 4: Upper Layer
Layer 6: Presentation	Encryption/Decryption	Layer 4: Upper Layer
Layer 5: Session	Session Management	Layer 4: Upper Layer
Layer 4: Transport	Error and Flow Control (across networks)	Layer 3: Transmission Control
Layer 3: Network	Interaction with Network	Layer 1: Network Access & Layer 2: Internet
Layer2: Data Link Layer	Error and Flow Control (across a link)	Layer 1: Network Access
Layer1: Physical	Bit Encoding	Layer 1: Network Access

3. Protocols

Standards (also known as protocols) based on the OSI architecture are developed by a voluntary group called "International Standards Organization (ISO)." These standards are then massaged and given formal authority by the International Consultative Committee on Telegraphy and Telephony (CCITT), which is part of the United Nations.

The OSI architecture consists of seven layers. The networking protocols are contained within the first four layers.

The United States Department of Defense (DOD) developed the TCP/IP network architecture. It consists of four layers. The networking protocols are contained within the first two layers (these correspond to the first four OSI layers). The OSI and TCP/IP architectures are compared in Figure 15.

Each layer has specific protocols for specific purposes. For example, EIA 232-D can be used for the OSI physical layer. This protocol defines the following five things:

1. **electrical**: uses NRZ-L bit encoding scheme;
2. **physical** connector: RS 232 25 pin connector;
3. **functional**: assigns each connector pin a given function;
4. **procedural**: specifies what computing equipment will do when it has a task to complete or when it receives a given signal on a given connector pin; example: when the Data Terminal Equipment (DTE) has data to send it will apply high voltage (<3V) on pin #4, when the Data Circuit-terminating Equipment (DCE) receives high signal on pin #4, it acknowledges with a high signal on pin #5.
5. **constraints**: distance between DTE and DCE is limited to approximately 50 ft (15m); limit of 20Kbps between DTE and DCE.

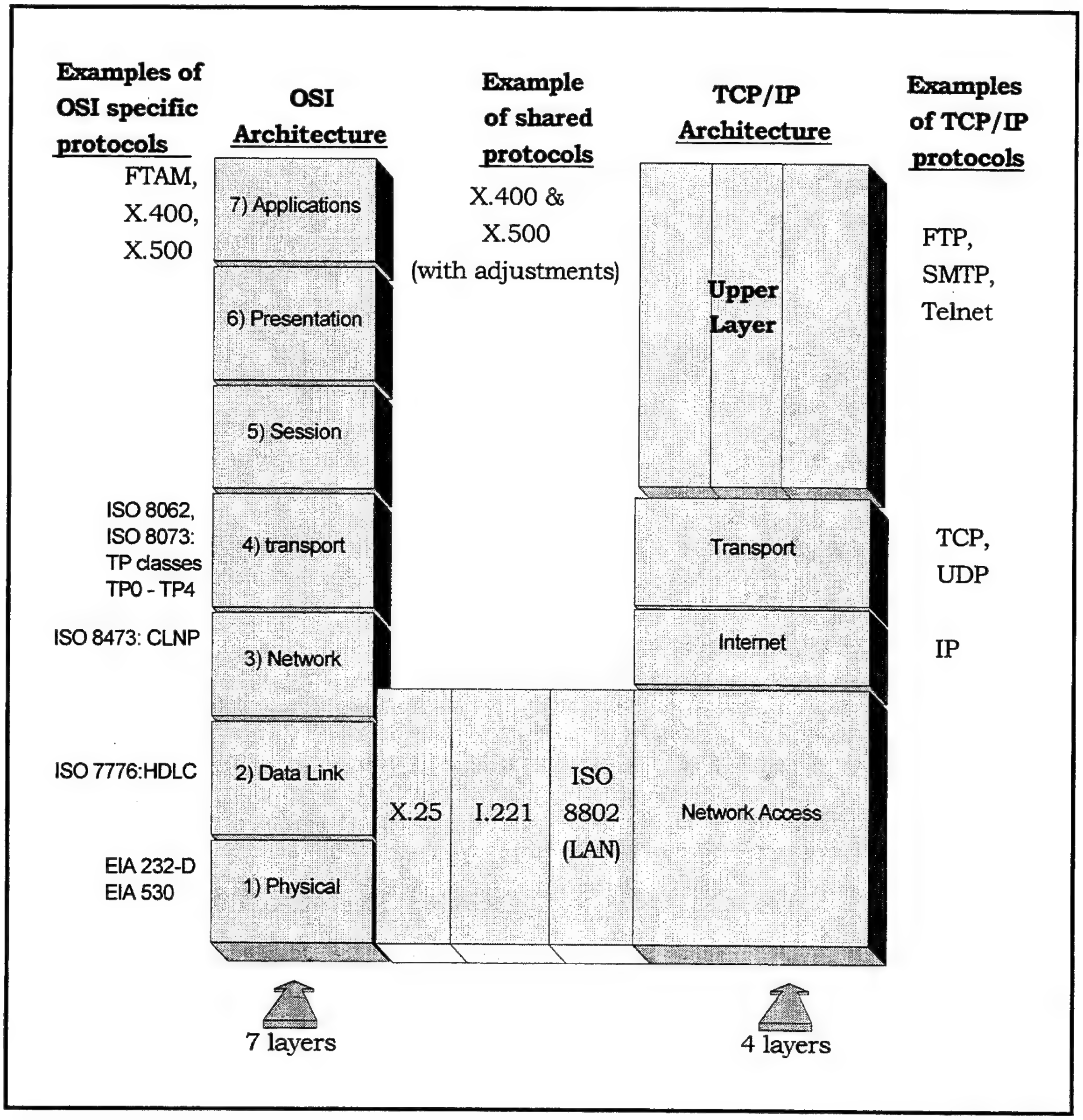

Figure 15: OSI & TCP/IP Architectures with Examples of Associated Protocols

There are also protocols which span across architecture layers. These protocols are for specific types of networks and incorporate various protocols from each layer. For example, X.25 spans the physical layer, data link layer, and half the network layer of the OSI model. It consists of the following protocols at layers 1-3 [Ref. 16]:

1. Layer 3: X.25 Packet Layer Protocol (PLP);

2. Layer 2: Link Access Protocol "B" (LAP-B);
3. Layer 1: X.21 or EIA 232-D.

Some of these protocols can be applied under either architecture. X.25 is a good example. If X.25 is used with the TCP/IP model, protocols for the internet, transmission, and upper levels would be applied. If X.25 is used with the OSI model, the CLNP protocol is applied to complete the network layer, then protocols for layers 4 - 7 are applied.

4. Types of Communication Networks

So why are there so many protocols? The protocols chosen to perform the functions of the different layers depend on the type of data sent, the type of network used to send it, and the method for completing each function that the engineer considers best for the situation. Since the protocols dealing with the telecommunications network are contained within the first four OSI levels (first two TCP/IP levels), we will limit the following discussion to those levels. Sections b5 - b8 correspond to the first four layers of the OSI model; they briefly describe: 1) the different types of circuits and 2) the methods for implementing the communications functions assigned to that architecture layer.

5. Physical Layer

As discussed earlier, there are two types of data: 1) analog, and 2) digital. The analog data can come from an analog source (i.e., voice, multimedia) or it can be digital information converted to analog by a modem. Analog data can only be carried on broadcast networks. Recall, these are networks which contain fixed, or dedicated, paths from sender to receiver. Digital information can come from a digital source (e.g., computer, ISDN telephone) or can be analog information that has been

digitized. Digital data can be carried on either broadcast or switched networks.

To compensate for loss of signal strength over long distances, analog circuits normally contain amplifiers at intermediate points to boost signal strength. In addition to boosting signal strength, the amplifiers also boosts any noise that has been introduced to the signal. As the signal travels from amplifier to amplifier, more noise is introduced, and subsequently amplified. This leads to a drop in the Signal-To-Noise ratio, a measurement of signal degradation. Digital circuits incorporate repeaters instead of amplifiers. As long as the digital signal is strong enough to recognize the individual bits are recognizable, the repeater regenerates the signal faithfully and sends it on. This prevents any noise introduced to the signal from being passed on from link to link.

6. Data Link Layer

The Data Link Layer is responsible for reliable transmission of data across a single switched network link, or from point-to-point across a broadcast network. There are three controls that lead to reliability:

1. error control;
2. flow control (at message level);
3. access control (at network level).

We will discuss various methods used to apply error and flow control. Access control applies mainly to LAN's; therefore, it is beyond the scope of this paper.

There are three types of error detection used in the DLL: 1) Parity Check, 2) Two-dimensional Parity Check (LRC and VRC), and 3) Cyclical Redundancy Check (CRC). To provide error and flow control, the signal binary bits must first be packaged with the overhead bits into frames.

There are three frame formats, depending on what the signal data is oriented to: 1) Asynchronous, 2) Character-oriented Synchronous, and 3) Bit-oriented Synchronous. Figure 16 (a, b, c) depict the various segments of each type of frame. If an error is detected, re-transmission of frame is requested.

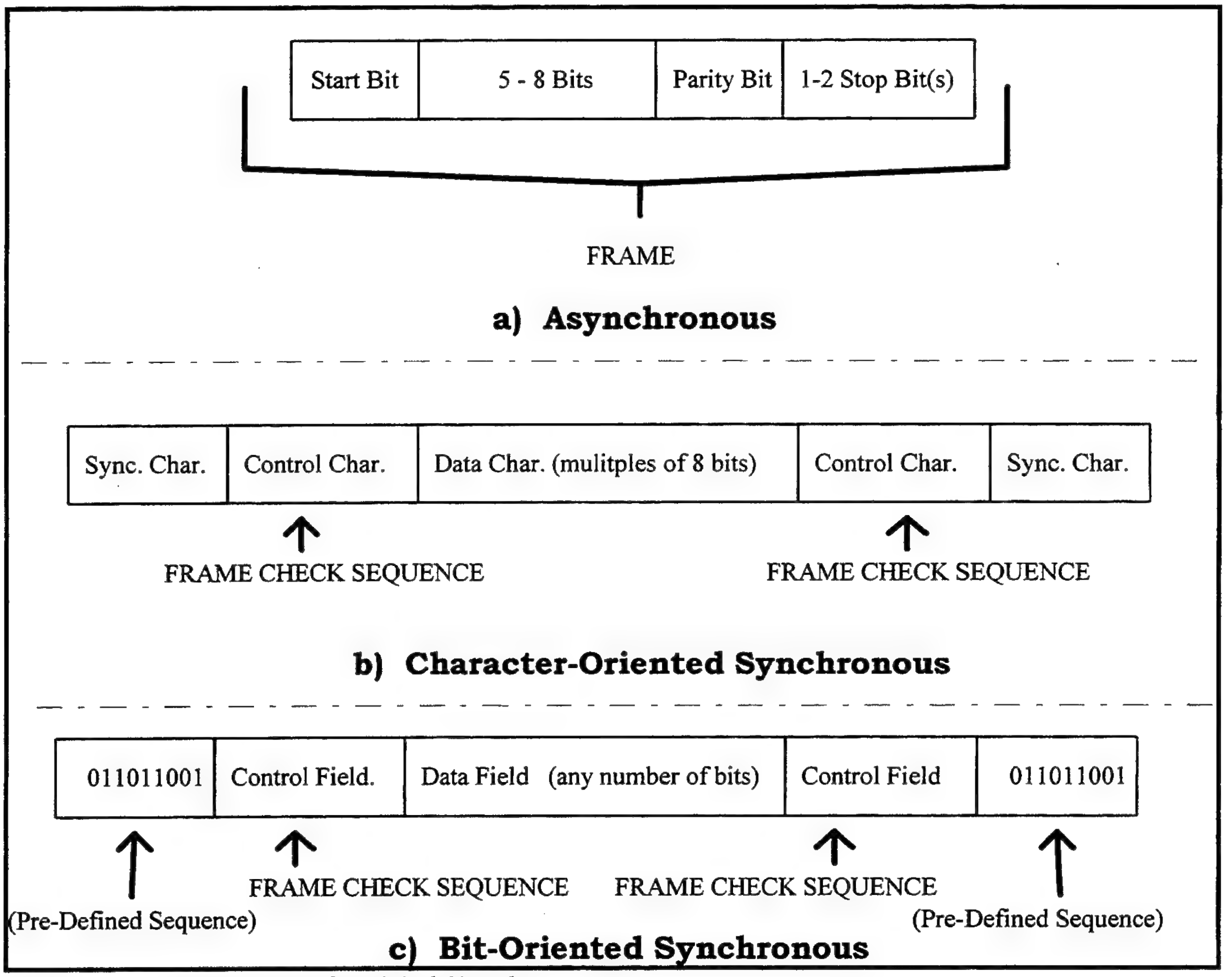

Figure 16: Frame Formats for Digital Signals

There are two methods used for flow control: 1) Stop & Wait, and 2) Sliding Window. Under the Stop & Wait method, the sending DTE sends one frame and waits for the receiving DTE to send a "received" acknowledgment. Once the acknowledgment is received by the sender, the sender will send the next frame, and so on. The Sliding Window utilizes a First-in/First-out (FIFO) buffer in the receiving DTE. The

sending DTE begins sending frames, not waiting for "received" acknowledgments. The "window" is the number of frames the sending DTE will send out before stopping and waiting for "received" acknowledgments to return. As the receiving DTE receives the frames, they are placed in the FIFO buffer. As the receiving DTE processes the frames, it sends acknowledgments back to the sender. If more frames arrive than the buffer can hold, they are automatically discarded. The sending DTE will send the number of frames specified for the "window." If it still has not received acknowledgment for the first frame in the window, it will time-out and automatically re-send that frame.

If an acknowledgment is lost, the sender will continue to send frames until the "window" limit is reached. It will then time-out and automatically re-send the unacknowledged frame. When the receiving DTE receives the same frame a second time, it will send a second acknowledgment, then throw away the frame (since that particular frame was already processed the first time it was sent).

If the receiving DTE detects an error (using parity or CRC checking), it will pass the frame back to the flow control. This will cause a negative acknowledgment to be sent back to the sending DTE. Upon receipt of the negative acknowledgment, the sending DTE will re-send the frame.

There is one more set of optional methods that can be applied under the "Sliding Window" method. These methods are called "Selective Repeat," and "Go Back-N." Anytime the receiving DTE has to send a negative acknowledgment, the following will occur under the two methods:

1. Selective Repeat - The receiving DTE will keep all additional frames it receives until the bad frame is received correctly (provided the buffer has enough room).

2. Go Back-N - Once a negative acknowledgment has been sent, the receiving DTE will dump all incoming frames until the bad frame is received correctly.

Anytime the sending DTE times out, the following will occur under the two (sub)methods:

1. Selective Repeat - The sending DTE will re-send only the frame that caused it to time-out. The receiving DTE will keep all additional frames it receives until the frame causing the time-out is received.
2. Go Back-N - Once the sending DTE times out, the sending DTE will begin re-sending all frames, beginning with the frame that caused the time-out. If the receiving DTE had received all the frames, it will dump them the repeated frames the second time they are received.

Table 7 summarizes the available Frame Format/Error Control/Flow Control combinations. As an example, the OSI's High-level Data Link Control (HDLC) uses the following combinations:

"HDLC $\Rightarrow$ Bit-oriented Synchronous $\rightarrow$ CRC $\rightarrow$ Sliding Window."

Table 7: Data Link Layer Frame Format/Error & Flow Control Combinations

Frame Format	Error Control	Flow Control
Asynchronous	Parity bit	Stop & Wait
Character-oriented Synchronous	LRC or CRC	Stop & Wait or Sliding Window
Bit-oriented Synchronous	CRC	Stop & Wait or Sliding Window

7. Network Layer

This section is mainly edited and abbreviated from Ref. 16. As mentioned before, the communication functions contained within the

network layer are not needed for broadcast or dedicated networks. The network layer is responsible for interaction with a "switched network" (i.e., circuit-switched, packet-switched, or fast packet-switched network) or a group of networks. The protocols contained within the network layer define:

1. the format of messages (or packets) deliverable across network(s);
2. how each message (or packet) format incorporates "connection-oriented" or "connectionless" network services;
3. which message (or packet) formats initiate and terminate network connections;
4. what each message (or packet) format does when messages (or packets) are lost or damaged within the network (i.e., error and flow control across the network).

After defining how "connection-oriented," "connectionless," and "fast-packet switching (FPS)" network services interact with networks, this section will discuss the various message (or packet) formats including their benefits and constraints. We will then use the X.25 protocol to illustrate how the sub-protocols (protocols contained within different levels of the X.25 protocol) apply the characteristics of the packet format and network service.

a. *"Connection-oriented" VS. "Connectionless" Service*

The two types of switched networks consist of "Connection-oriented" and "Connectionless." Both services share one trait, both use what is called "store and forward" message delivery. This simply means that the message, or packet, is passed from network node to network node; at each node, the message (package) is stored in either memory or on disk until the node can transmit the message (package) on to the next node.

Connection-oriented service is also known as "virtual circuit service." This network-layer service goes through three stages: 1) establishes connection, 2) transfers data, and 3) disconnects connection. Rather than establishing a dedicated circuit, it establishes a "logical circuit"; this means that all the data packets will pass through the same nodes until finally reaching the destination. This type of service does the following:

1. it assures that the packets will arrive in the same order as sent;
2. it allows the network nodes to request re-transmission as soon as a packet is lost or damaged;
3. the nodes can pass the packets to the next node faster because it does not have to strip the frame from the data and repackage it in a frame containing the next node address;
4. it allows other data from various sources, to use the same lines; thus providing greater line efficiency.

Connectionless services come in two flavors: message-switched and datagram. Connectionless services do not use the same path for an entire session like the connection-oriented. Instead each node makes a decision based on information it receives from the surrounding nodes. Each node chooses the "least cost" node out of the nodes that are available. The network control center decides which node is the best alternative (least-cost). This decision-making has nothing to do with the network layer.

The message-switched service passes the whole message at one time. Once the message is received at a node, it is temporarily stored on disk and then passed on to the next available "least-cost" node. Since messages can vary to practically any length, the delay at each node (consisting of receiving time plus queuing delay time) will be relatively

long and highly variable. This makes message-switching inappropriate for real-time or interactive systems.

Datagram services send packets of data; they also limit the size of each packet. This, in turn, limits the delay experienced at each node. The packets are small enough to be stored in memory rather than on disk. However, since each packet is sent to the next "least-cost" node, and does not follow a given route, the packets can arrive at the destination out of order. Table 8 sums up the differences between the connection-oriented and connectionless services.

Table 8: Network Layer Services Summary

			packet-switched	
circuit type	**circuit-switched**	**message-switched**	**datagram**	**virtual-circuit**
data transfer	dedicated path	store & forward	store & forward	store & forward
type of data	N/A	message	packet	packet
type of route	dedicated route for entire session	route for each message	route for each package	route for entire session (using control packet)
benefits	* little end-to-end delay, circuit is established * best for bulk data	* no limit on message size * greater line efficiency	* does not have to establish a virtual circuit * greater line efficiency	* provides link-to-link error & flow control * packets arrive in order sent appropriate for real-time & interactive traffic * greater line efficiency
constraints	* inefficient for burst traffic * calls may be blocked	* delay at each node * inappropriate for real-time or interactive traffic	* packets may arrive out of order * inappropriate for real-time & interactive traffic	* short delay while virtual path is established

b. *Fast-Packet Switching (FPS) Services*

Fast-packet switching (FPS) services are connectionless services that utilize permanent virtual circuits (PVC) established by the network manager. FPS includes both frame-relay and cell-relay technologies. They are designed for high throughput and low traffic delay while retaining the efficient line-sharing of regular packet-switching networks. The high throughput and low delay is accomplished by stripping some of the protocol processing out of the service. FPS does not provide any network link-to-link error or flow control. Due to the high speeds at which information is delivered using FPS, it is more efficient to allow the network layer at the DTE to request a re-transmission, rather than check each message at every link.

The two basic types of FPS include "frame relay" and "cell relay." The basic difference between the two is the length of the packet. The frame relay allows for variable length packets while cell relay standardizes the packet (in this case called a "cell") length at 53 bytes. By using a standardized cell size, cell relay can implement hardware-based switching. Hardware-based switching can occur much faster than software-based switching. Because of the variable frame size, frame-relay must use software-based switching. Frame relay can provide service up to 1.5 Mbps, while cell relay can provide up to a minimum of 2.5 Gbps. However, due to the small 48-byte data package contained in each cell, cell relay has a much higher overhead (~10%) compared to frame relay (~0.33% - 4%).

> "As a general rule, the lower the speed (e.g., T1 and sub T1), the more concerned you are with overhead for data applications...At levels of T3 and above, the benefits of ATM outweigh the efficiency considerations. At relatively lower speeds (T1 and below), frame relay more efficiently transports data." [Ref. 17]

c. *The X.25 Protocol*

We will use the X.25 protocol to show how network layer protocols are made up of sub-protocols to interact with the underlying layers. The X.25 protocol is a connectionless, virtual circuit, packet-switching protocol.

At the network layer (layer 3), X.25 consists of the X.25 Packet Layer Protocol (PLP). The X.25 PLP defines the necessary packet formats, such as the data and control packets. It also defines:

1. what control packets are exchanged in order to establish or disconnect a virtual circuit;
2. a sliding window for error and flow control.

At the datalink layer (layer 2), X.25 consists of the LAP-B (Link Access Protocol; a subset of HDLC) protocol. This layer provides the link-to-link error & flow control for the virtual circuit. At the physical layer (layer 1), X.25 consists of the X.21 layer 1 protocol (or EIA-232-D). We covered this protocol back in section B-3.

8. Transport Layer

The transport layer provides error control at the network level. It also consists of connection-oriented and connectionless services.

a. *"Connection-Oriented" VS. "Connectionless" Service*

Connection-oriented transport services establish, maintain, and terminate the logical connections between transport users. They also ensure reliable end-to-end sequenced delivery and error & flow control.

The ISO transport protocol for connection-oriented is known as "ISO TP (or ISO 8073)." There are five different classes of TP available, each providing different levels of error control. They are as follows:

1. class 4 (TP4) error detection & recovery;

2. class 3 (TP3);
3. class 2 (TP2);
4. class 1 (TP1) basic error recovery;
5. class 0 (TP0) simple class.

ISO TP-4 is functionally identical to the DOD TCP standard.

The connectionless protocol is "ISO 8062." This protocol is used by applications that favor speedy handling over reliability; they do not need reliable transmission of messages. ISO 8062 corresponds to the DOD UDP standard.

9. Conclusion

In this section, we have reviewed some of the basics of communications to assist the design team in understanding the origin and purpose of various protocols. It is hoped that this section will be a useful reference.

C. MICROWAVE SYSTEMS

In a microwave system, the transmitting and receiving equipment must be designed for the frequency selected, for the given transmission, and for the bandwidth required [Ref. 14].

A microwave system consists of end sites and relay sites, as illustrated in Figure 17. A simplified illustration of a typical relay station, as part of the transmission channel, can be seen in Figure 18.

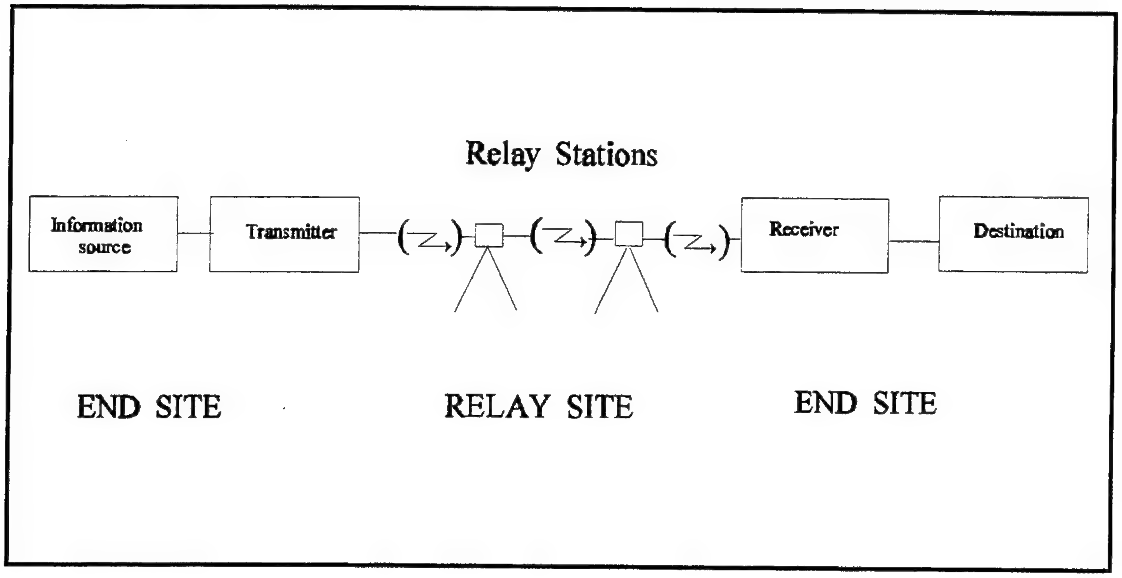

Figure 17: Microwave Relay Block Diagram

The basic function of the relay link is to receive the wave from the preceding station, amplify it by the desired amount, and radiate it toward the next station.

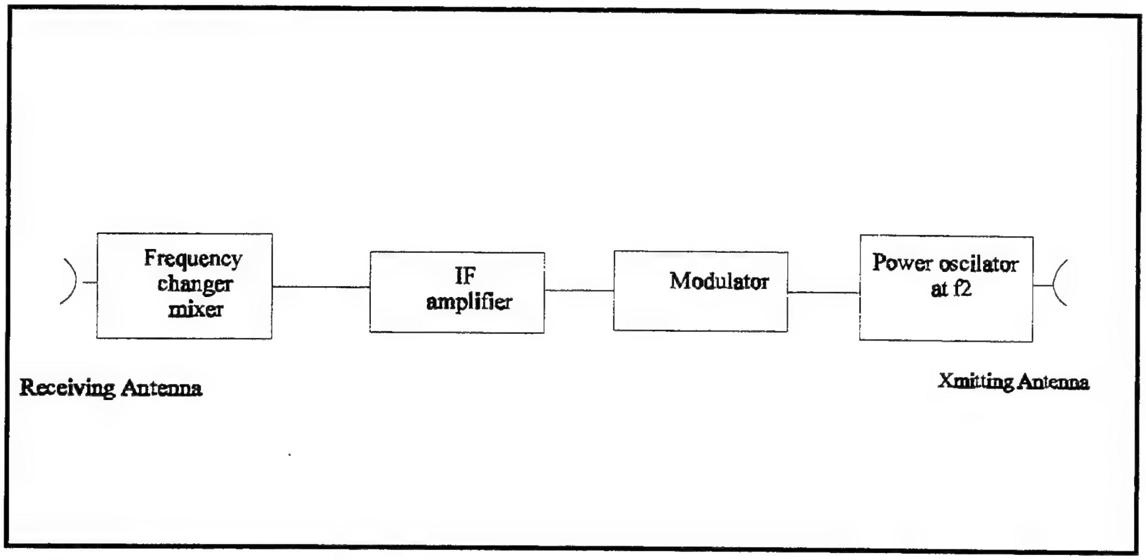

Figure 18: Simplified Microwave Relay Component Diagram

A microwave site, of course, is not as simple as these diagrams portray. The system design will have to consider an interplay among a number of factors The following are some examples :

1. In selecting a carrier frequency, the higher this frequency, the greater the bandwidth that can be obtained for the channel and the smaller the antennas for a given antenna gain. However, the efficiency and reliability of available amplifiers is lower. At too high a frequency, atmospheric and rain attenuation may also occur along the propagation path.

2. The larger the antennas for a selected carrier frequency, the greater the antenna gain. This permits either lower amplification at each station or a greater station spacing for a given amplifier. However, large antennas with a large wind loading increase the cost of each station; thus these advantages and disadvantages must be balanced.

3. The use of tall towers or selection of station locations on high mountains offers the best propagation possibilities. This may permit greater station spacing or less expensive repeater design. However, it may increase the cost of construction or maintenance of the station.

4. Using wide bandwidth channels permits greater signal multiplexing or lower signal-to-noise ratios, hence greater station spacing, up to a certain point. The design of very broadband amplifiers and other components becomes expensive, and noise figure may decrease the signal strength faster than the bandwidth improves it. Thus, a parallel link may be a better solution for increasing channel capacity beyond a certain point.

In the design problem, interrelations among transmitted frequency, antenna size, transmitted power, receiver noise figure, and characteristics of the propagation path are again important. Pulse width and repetition rate offer two additional variables to the equation.

One of the alternatives for BACS is the use of higher frequency digital microwave system. For this purpose, a number of factors must be examined to understand the affects of a higher frequency.

From a general standpoint, the design of a general microwave link requires performing an iterative sequence of the following steps :

1. Path and site selection;
2. Propagation and interference;
3. Selection of equipment capable of satisfying the availability objectives set for the route;
4. Final calculations.

The microwave beam behaves much like a light beam as far as atmospheric influences are concerned. It is also subject to other external influences as described in the following discussion.

1. Influence of Terrain and Obstructions

The microwave beam is influenced by the intermediate terrain between stations and by obstacles. It tends to follow a straight line in azimuth unless intercepted by structures in or near the path. In traveling through the atmosphere it usually follows a slightly curved path in the

vertical plane, i.e., it is refracted vertically due to the variation with height in the dielectric constant of the atmosphere. Generally, this refraction is slightly downward, so that the radio horizon is effectively extended. The amount of this refraction varies with time due to changes in temperature, pressure, and relative humidity. These control the atmospheres dielectric constant.

The beam can be reflected from relatively smooth terrain and water surfaces, just as a light beam is reflected by a mirror. This occurs mainly at small angles of incidence. A good illustration of this can be seen in the case of an asphalt highway. When viewed directly, the surface looks slightly rough and does not reflect light well; however, when viewed from a distance at a very small angle, it looks like a mirror or wet surface.

An important concept in analyzing microwave propagation effects, particularly those of diffraction, refraction, reflection, and the effects of terrain and obstructions, is that of the Fresnel zone. The first Fresnel zone radius is a kind of "rubber" unit, which is used to measure certain distances (path clearances in particular) in terms of their effect at the frequency in question, rather than in terms of feet. The second and higher order Fresnel zones are also very important under certain conditions, such as highly reflective paths.

Although a microwave beam is conventionally shown as a line, the actual method of propagation is as a wave front, and the important portion of the wavefront involves a sizable transverse area.

In order to ensure free space propagation, it is essential that all potential obstructions along a path are removed from the beam centerline by at least 0.6 F1 , where F1 is the radius of the first Fresnel zone at the point of the obstructions.

Because refractive bending varies in cycles daily and changes erratically at times, the clearance over the intermediate terrain must be adjusted to minimize the losses during extreme bending conditions. This calls for a path clearance over immediate objects somewhat greater than line-of-sight. Normally, the beam is bent downward by atmospheric refraction. Though, at times, the atmospheric conditions may be such that the beam is bent upward, effectively reducing the clearance over terrain in the path.

2. Fading

Fading is a general term applied to loss of signal as seen by the radio receiver at its input. The term is intended to apply to propagation variables in the actual radio path.

The actual fading is the change in path loss between the transmitter at one station and its receiver at the following station. These changes in path loss have to do with atmospheric conditions and the geometry of the path.

The effect of fading on radio paths is much greater than the attenuation variables of open wire and cable carrier systems, which are primarily due to the effect of temperature variations in the metallic medium. Radio fading is caused by refractive, diffractive, and reflective effects in connection with the atmosphere and fixed objects. Fading can result in defocusing, blocking, and sometimes cancellation from multiple paths of varied lengths, due to the resultant variation in phase angles on arrival at the receiving antenna.

Although the atmosphere and terrain over which a radio beam travels have a modifying effect on the loss in a radio path, there is, for a given frequency and distance, a characteristic loss. This loss which is known as the free space loss increases with both distance and frequency.

> The source of greatest loss in a typical radio transmission path is free-space loss (FSL) resulting from the propagation of the transmitted signal of frequency (F_{MHz}) over the distance (D) in statute miles between EIRP and receiving antennae.[ref. 18, p. 11].

Changing from 2Ghz to 8Ghz can have a great affect on the FSL. For example, the existing microwave shot from Monterey to Mount Umunhum is 38.06 miles. As we can see in Table 9, the average loss from changing to 8GHz is 12.1 dB. [Ref. 18, p. 11]

Table 9: F_{MHz} VS FSL Loss at 38mi.

F_{MHz}	D_{mi}	FSL_{dB}
1,736	38.06	132.98
1,843	38.06	133.5
7,500	38.06	145.69

This loss, in addition to the other variables, indicates the current site locations within the BACS system must be re-evaluated for operation at the higher frequency.

3. Atmospheric Effects

For frequencies below about 100 GHz, attenuation caused by snow, hail and fog can generally be expected to be significantly less than rainfall attenuation for most regions of the earth. Under this circumstance, design considerations for fading margins required for precipitation attenuation can be based on rainfall statistics alone [Ref. 19].

Attenuation of microwave signal due to rainfall along the path is present to some degree at all microwave frequencies. At higher frequencies the excess attenuation due to rain increases rather rapidly and, in the bands above about 10 GHz, is great enough to significantly affect path length criteria, except in areas of very light precipitation [Ref. 20] .

The degree of attenuation is a function of a number of variables including the frequency band, size and shape of the drops, and the

distribution of rain (in terms of its instantaneous intensity) along the path. What is important is not the total amount of rain which falls over an extended period, but rather the maximum instantaneous intensity of fall which is reached at any given moment, and the size of the area over which the high intensity cell extends at that moment.

The San Francisco Bay Area average monthly rainfall statistics is given in Table 10[4]. This figure reveals that the rainfall is quite intense during the winter season.

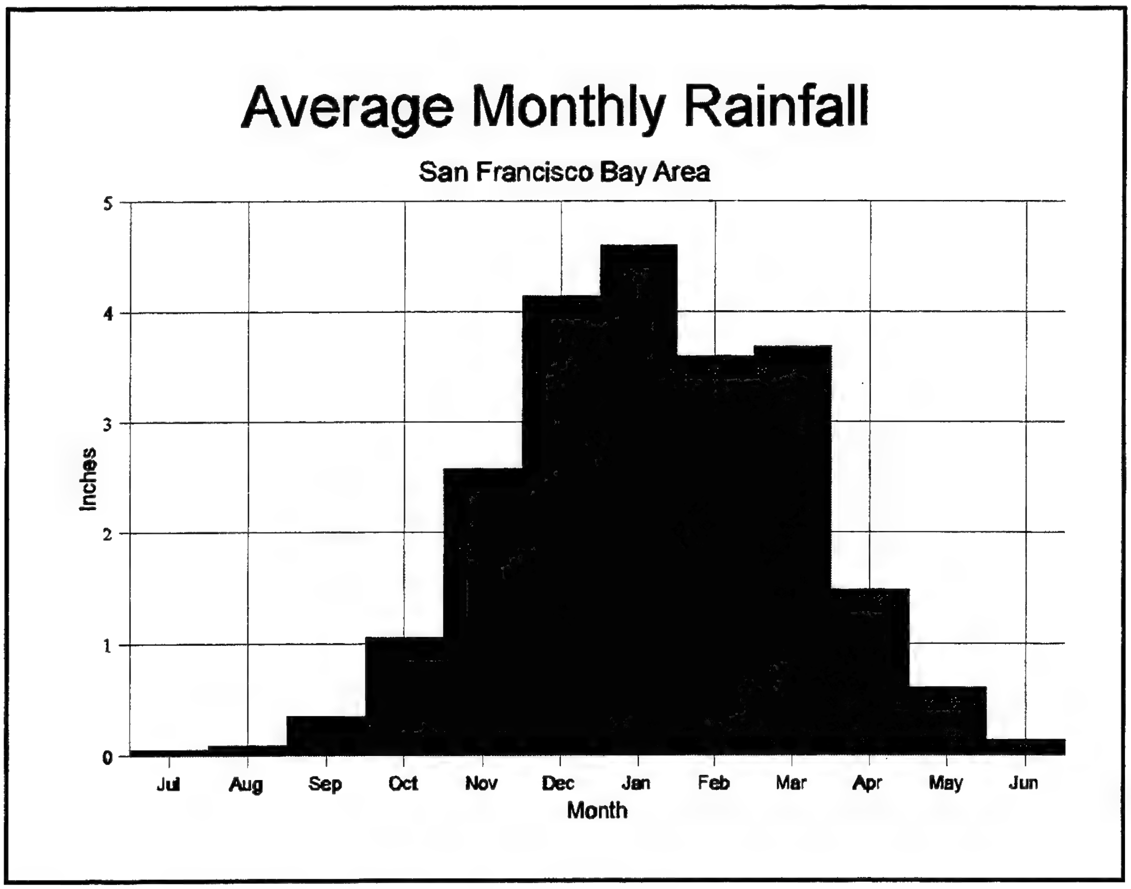

Table 10: Average Monthly Rainfall in San Francisco Area

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[4] Courtesy of the San Francisco Weather Forecasting Service.

Two things to bear in mind in connection with rain attenuation are: (1) multipath fading does not occur during periods of heavy rainfall, so the entire path fade margin is available to combat the rain attenuation, and (2) neither space diversity nor in-band frequency diversity provide any improvement against rain attenuation.

In practice, signal attenuation due to fog is usually modest compared with the attenuation rates for rain. On rare occasions, the liquid-water content can become as high as 0.5 to 1.0 g/m^3 in very dense radiation fogs. Such fogs can be expected to produce attenuation rates comparable to those caused by rain

Fog which occurs very close to the ground in the early morning, usually in a valley immediately over a small stream, has quite another effect. In this case, the normal beam is in the clear, but the surface at the fog layer is a smooth strata which forms a good reflector of microwave energy [Ref. 19] .

4. Site Selection

Terminal sites are normally located at enterprise facilities. However, the relay sites are located with emphasis on propagation over the intermediate paths, and possible interference from internal or external sources.

The choice of relay sites is greatly influenced by the nature of the terrain between sites. In preliminary planning it may be assumed that, in relatively flat areas, the path lengths will average between 25 and 35 miles for the frequency bands from 2-8 GHz. Distances greater than 35 miles between two sites may cause system degradation.

5. Equipment

The characteristics of the microwave system components to be used affect the engineering choices and path performance parameters. Thus, the survey engineers must know in advance:

1. frequency bands to be used;
2. type of service (analog/digital);
3. number of channels (both present and future);
4. performance and reliability criteria desired;
5. parameters of the microwave equipment to be used (i.e., transmitter output power, receiver noise figure, bandwidth, etc.).

Primary considerations during the selection of the microwave radio equipment include:

1. Characteristic of the end-to-end baseband facility, including bandwidth, frequency response, loading capability, noise figure, and noise performance;
2. The amount of radio gain available, as determined by transmitter power output and receiver noise characteristic;
3. Operating frequency band, and required frequency spacing between radio channels, as determined by transmitter deviation, receiver selectivity, and frequency stability;
4. Primary power requirements and options available;
5. Supervisory functions available, including order wire, alarms, and controls;
6. Equipment reliability, including availability of redundant versions such as frequency diversity, 1-for-N or 2-for-N multi-line switching, hot standby, or hot standby at transmitter and space diversity at receivers;
7. Provisions for testing and maintenance.

Towers have a significant effect on many microwave path engineering choices. Prior knowledge of the tower limitations is critical.

These include wind, , weight, and height limitations to name a few. The type of waveguide and transmission lines to be used is important, not only for their loss characteristics, but also for the degree of impedance matching attainable. This effects the echo distortion noise. Transmission line characteristics become extremely important with high density systems having long waveguide runs.

The type and the size of the antenna that will be used depends on several variables. The most important ones are the gain, the area of antenna aperture, and the wavelength at operating frequency. The existing tower must also be considered.

6. Propagation and Interference

The final objective for any microwave system is to provide the most cost-efficient, distortion-free, and interference-free service continuity for the type of service assigned. Overall reliability, or service continuity, involves not only equipment failure rates and power failures, but also the propagation performance of the individual paths. This involves antenna sizes and elevation, frequency or space separations in diversity systems, path lengths, and frequency attenuation relationships. It also includes fading margins which, in addition to path parameters, are affected by noise figure, transmitter power, and attenuation of waveguide, and filter arrangements.

Distortion may occur in the radio path, but more often it occurs due to poor return loss of amplifier components, waveguide filters, and antennas. Also the characteristic of switching devices and/or combiner's are involved [Ref. 21].

D. SATELLITE

The satellites can be classified as "geostationary" or "low orbit" depending on their distance to the earth. The distance of geostationary satellites to earth turns out to be a disadvantage because of propagation delay. This delay is caused by the information traveling a minimum of 45,000 miles before the data is received by the user facility. Large block sizes are used to improve efficiency. However, due to the delays encountered, recovery of errors in blocks of information becomes time consuming and costly. Therefore, the geostationary satellites are not suitable for applications that require very short response times. [Ref. 22]

As an answer to this problem, several consortiums have planned extensive low-altitude, thus non-geostationary, satellite communications systems. These low-altitude orbits have a much shorter propagation delay, which is necessary for real-time duplex communication. These orbits also provide small propagation loss, allowing the use of low power and smaller satellites and earth station antennae.

Most vendors offer three types of service: 1)channel-based, 2) carrier-based, or 3) leased services. Individual channels for services less than T-1 may be leased while wideband applications are normally purchased.

The author has found two existing commercial satellite systems (Inmarsat and AMSC) and three other systems that are in various stages of development. Since Inmarsat has been operating since 1982, we will discuss it in some detail. We will then briefly discuss the other four systems.

1. The Inmarsat System

Inmarsat is an international organization operating the only global satellite system for mobile communications. The organization was

established in 1979, mainly on the initiative of the International Maritime Organization (IMO), with an initial mandate from its communications system to serve the maritime community by improving communications and the radio-navigation for safety of life at sea and efficient ship management.

By convention, the Inmarsat space segment is open for peaceful, non-discriminatory uses by all nations, whether members of Inmarsat or not. The organization is required to provide services in all geographical areas where there is a need for mobile communications . Coverage now exists over the whole globe except the extreme polar regions.

From Inmarsat's point of view, it is role is clearly divided into two main areas:

1. providing the space segment for instant reliable distress and safety;
2. a general satellite communications for the maritime community.

Inmarsat has two major satellite communications systems designed to provide most of the medium and long range communications functions: Inmarsat-A and Inmarsat-C. Inmarsat also offers Inmarsat-E, and 1-band EPIRB system.

The Inmarsat system, like most satellite-based communications systems, is comprised of three segments:

1. the space segment;
2. the ground control facilities;
3. the end-user's Mobile Earth Station (MES), also known as Ship Earth Stations (SES) in the maritime environment.

a. *Space Segment:*

The space segment is planned, procured, maintained, and operated by Inmarsat, and financed by the Inmarsat Signatories.

Inmarsat started commercial operations in February 1982 with leased satellite capacity from Comsat General, Intelsat and the European Space Agency (ESA).

In 1982, Inmarsat launched its own satellite system composed of four satellites built by British Aerospace and Hughes Aircraft. Each of these new satellites has a total L-band EIRP of 39 dB_w transmitted though a single global beam enough to support more than 250 Inmarsat-A type channels. Each satellite was designed for a ten-year life mission in orbit and should be available for service well beyond the year 2000.

In 1991, Inmarsat signed a contract with a consortium led by GE Astro and Marconi Space Systems to procure a first batch of four, third-generation satellites (Inmarsat-3). These represented the most technologically advanced mobile satellite developed at the time. Each Inmarsat-3 satellite has eight times the L-band power of an Inmarsat-2 satellite (i.e., 48 dB_w compared 39 dB_w). In addition to global beam coverage, each Inmarsat-3 satellite provides coverage to four or five transmit-and-receive spot beams at L-band. The first of these satellites was scheduled for delivery in late 1994.

b. *Land Earth Stations:*

A worldwide network of gateway Land Earth Stations (LES), or Coast Earth Stations (CES) for maritime purposes, provide links for the end user, through the satellites, to the terrestrial public switched telecommunications network. LES are owned and operated by telecommunications authorities, mostly Inmarsat Signatories, which provide the mobile services to the end users.

c. ***Mobile Earth Stations:***

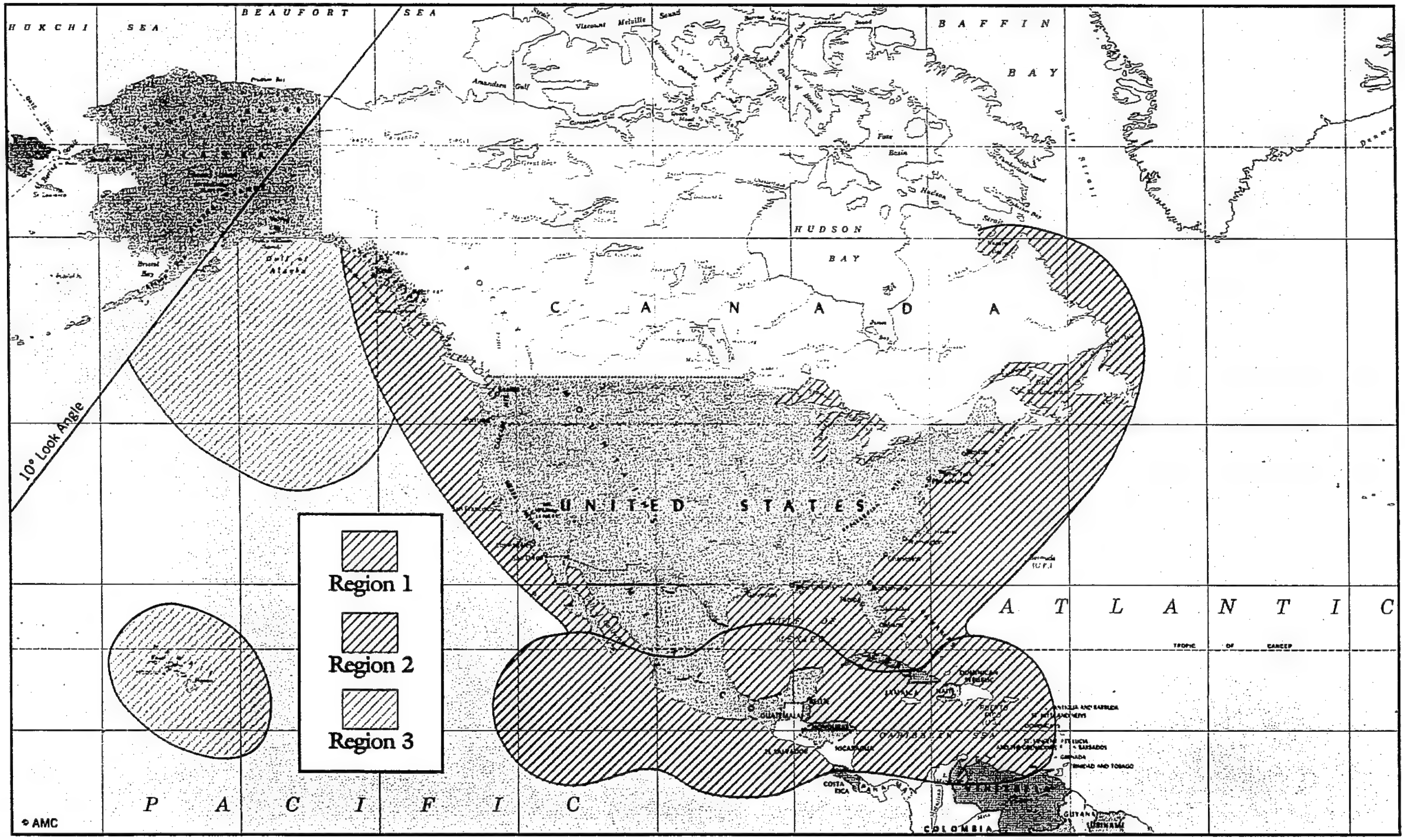
The Mobile Earth Station (MES), Known as Ship Earth Stations (SES) in the maritime environment, are obtained from a number of manufactures and are commissioned by Inmarsat to utilize the system.

At present, there are two families of Inmarsat satellite communications equipment available to mariners. Inmarsat-A is the larger and more versatile, offering voice, data, facsimile and telex-based communications. Inmarsat-C terminals are smaller and offer text and data messaging at lower speeds.

2. American Mobile Satellite Corporation (AMSC)

The AMSC was established in 1988 and has been licensed by the Federal Communications Commission to provide mobile satellite services. As Figure 19 shows, AMSC coverage includes most all of North America, extending approximately 200 miles out to sea.

AMSC services are provided through one satellite in geosynchronous orbit 22,300 miles above the equator at 101° West Longitude. AMSC also has an agreement with a sister Canadian company for backup satellite coverage, in case of failure. The satellite uses six spot beams and 30 MHz of L-band spectrum to provide transmission coverage. Using the Ku-band, the satellite can receive



Standard coverage area assumes standard equipment configuration, including the stabilized midgain antenna (G/T=-16dB/K). Higher gain antennas may increase technical service area. These coverage contours represent estimated receive power at L band frequency=1.5300 GHz. This map displays the result of statistical and experimental analysis of the AMSC satellite. Actual coverage may vary.

Figure 19: AMSC Maritime Standard Coverage Area

private network transmissions from anywhere in North America. This band is also used for the satellite uplink gateway located 14 miles from Reston, VA. A diversity uplink site is provided under an agreement with Washington International Teleport. The two site are connected by a full-time analog fiber optic circuit leased from Bell Atlantic. [Ref. 23]

AMSC will offer voice, fax, and switched data services in the following four areas:

1. satellite telephone service: consists of satellite-only telephone service;
2. satellite roaming service: extends cellular services to all coverage areas. Subscribers place calls via cellular network when traveling in cellular coverage area. Outside of coverage area, calls are processed via satellite [Ref. 24, p. 6] ;
3. fleet management services: in addition to above mentioned services, fleet management provides nationwide voice dispatch and position location services. These services are available to maritime, ground vehicles, aviation, and fixed sites.
4. private network capacity: offers satellite capacity, switched service and network management to private network customers..

3. Prospective Satellite Projects

a. *The Iridium System:*

A consortium led by Motorola plans to launch 66 low-earth orbiting satellites as part of it is $3.4 billion Iridium effort; it is expected to provide 2.4 kilobit/sec data transmission to mobile users. [Ref. 25, p. S36]

b. *Teledesic System:*

A consortium led by Microsoft and McCaw Cellular plans to launch 840 low-orbit satellites delivering voice, data, and video services at speeds up to 16 kilobit/sec.[Ref. 25, p. S36]

c. *GlobalStar System:*

Supported by Loral Corp., Qualcomm Inc., and PacTel Corp., Globalstar plans on launching 48 low-orbit satellites in 1998. At a cost of $275 million, they plan to offer data transmissions at 9.6 kilobit/sec. [Ref. 25, p.S36]

E. WIRELESS TECHNOLOGY

A wireless network providing alternative routing for the VHF National Distress System would provide the required duplexing features and could be an innovative approach. A standby cellular and satellite alternative routing system, such as the one illustrated in Figure 20, has been proposed by the American Mobile Satellite Corporation for alternative routing. In the event of leased-line failure, switching equipment would attempt to re-establish the VHF NDS link via the cellular network. If this link could not be established, the switching equipment would then re-establish the link using the AMSC satellite.

Corporate owned cellular telephone systems operating in the San Francisco area theoretically encompass all the CG facilities in the area. Figure 21 shows the San Francisco Bay area coverage for Cellular One Inc.. This existing cellular system has numerous overlapping cells with emergency power services immediately available. Information concerning the actual operational availability of the individual cellular companies is treated as "corporate secrets"; they are, however, considered to be at least 99.5% [Ref. 26, p. 359].

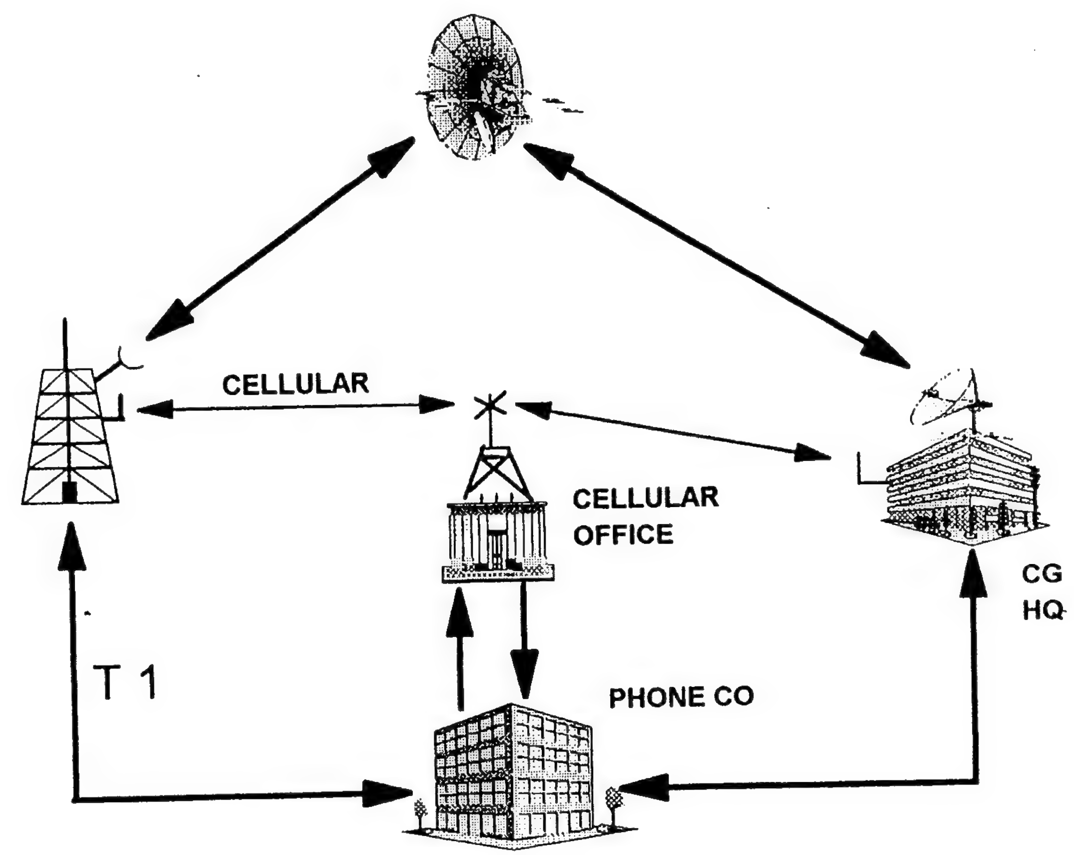


Figure 1: Standby Cellular/Satellite Alternative Routing Illustration

Red: Indicates local calling area.
Orange: Indicates Cellular One North American Cellular N/W

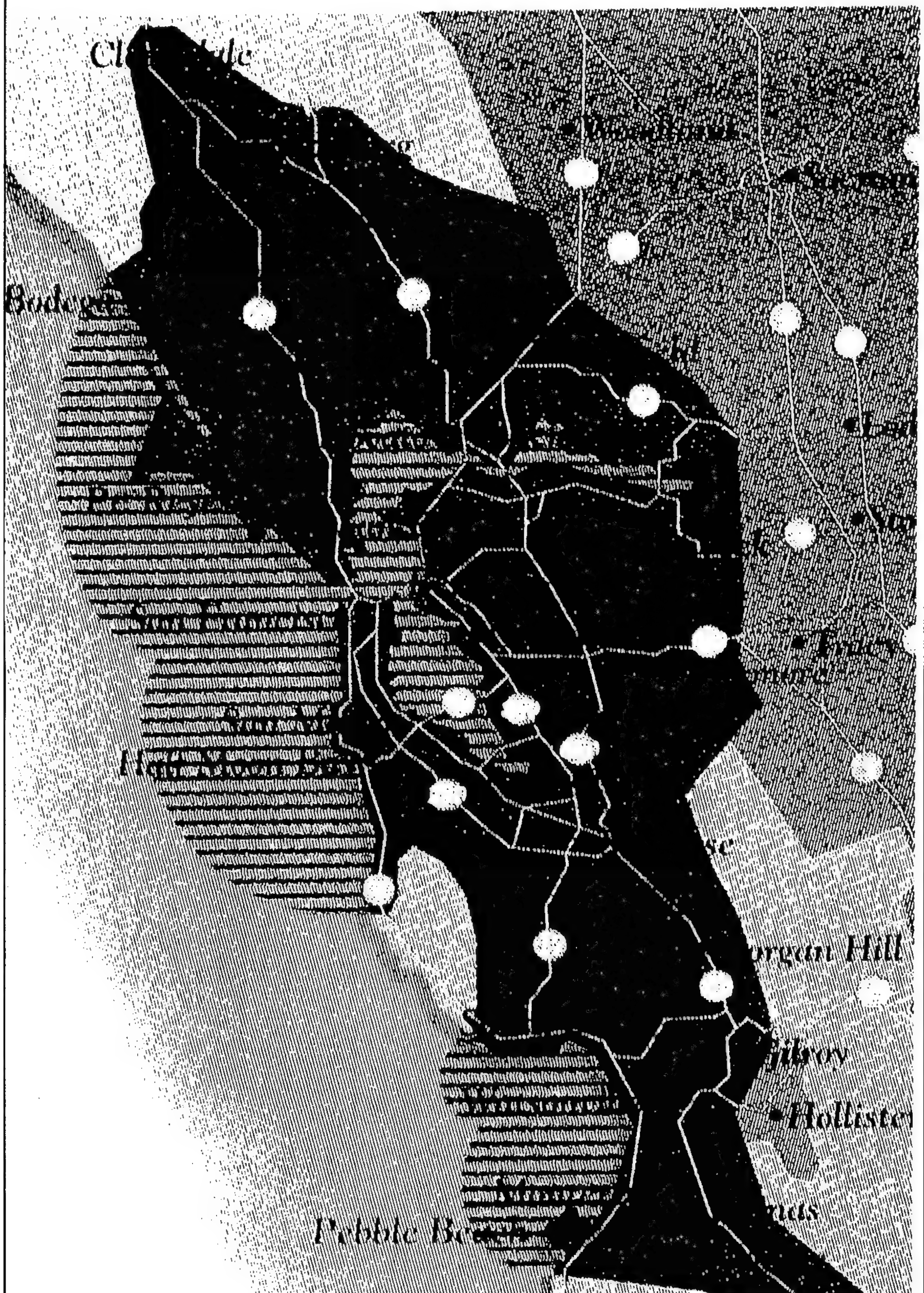


Figure 21: Cellular-One Coverage of the San Francisco Area

A wireless telephone network could be quickly expanded during emergencies to facilitate the required communications between CG command centers and on-scene commanders. It could also be designed to aid in the relocation of command resources in the event of failures or during an emergency, such as an earthquake.

Although this technology has never been used by the CG in this manner, the alternative deserves to be fairly evaluated.

F. CONCLUSION

The purpose of this chapter has been to review some of the basic communication services, protocols, and technologies available today. It is intended to give the design team an initial understanding of the technology that is available today and where technology is headed tomorrow.

Although developed separately, many companies have developed interfacing schemes that allow various standards and transmission media to be integrated into a single WAN.

VII. SYSTEM MIGRATION

A. INTRODUCTION

This chapter covers phases five and six of the Structured Approach Model. In the fifth phase, "Develop Migration Candidates," we will discuss the factors involved when developing a list of alternative migration paths that can be used to reach our target architecture. In phase VI, "Select Migration Path," we will discuss some useful methodologies to help us determine the most cost-effective configuration from the list of alternatives and analyze our projects' level of sensitivity to change.

In the previous chapters we used the three views to help us visualize aspects of the project we may have otherwise overlooked. In the author's opinion, the "organizational" and "functional" views during these two phases mainly serve as "checklist" reminders. This reminds us to check that any changes to business processes, and that all functional requirements, are implemented within each alternative. On the other hand, the physical view begins to take form as we move from standards and technical capabilities into the actual details of alternative configurations. Therefore, our discussion of these two chapters will develop around the required tasks, rather than the views being used at the time.

B. DEVELOP MIGRATION CANDIDATES

1. Limiting the Number of Migration Paths Considered

There are a number of factors that can be varied, each of which could affect the final network configuration. Some of the factors that can vary between possible candidates include:

1. the level of functionality attained for "should have" and "nice to have" requirements (this goes for both the users systems and the telecommunications network);
2. the timetable for implementing the various technical capabilities;
3. the technologies used for implementation; this includes the users systems, telecommunications transmission media, and type of network management software chosen.

The number of candidate migration paths is the product of the following equation:

$$X = \left(F_n\right)^{\sum_{1}^{n} Variations}$$

Where,

X = number of candidate migration paths

F_n = number of factors

Variations = number of variations for each factor

Equation 1: Migration Path Alternatives Calculation

Each time a factor variation is added, the number of new candidate paths increases by a whole magnitude. Therefore, we must find ways to limit these variations. Dr. Emery states:

> Since each alternative examined entails a certain amount of effort, the number must be limited to three or four substantially different alternatives. It is important, though, that they encompass a wide range of characteristics so that attractive options will not be overlooked.
>
> At the low end of the range, a bare minimum design should aim only at satisfying the "must have" user needs (with perhaps some of the more cost-effective "should haves" thrown in for good measure). A high-end system should meet most of the "should have" and many of the "nice to have" requirements. This wide range is quite likely to bracket the design that provides the best balance between cost and benefits. [Ref. 27, p. 232]

Although any limitation increases the risk of overlooking the one optimal candidate path, by using common-sense and deliberation to make and apply assumptions, the design team should be able minimize both the factor variations and this associated risk. All assumptions made, including factors leading to the assumptions, should be recorded in the project folder. If there are no communicable reasons for reaching an assumption, record this fact. There is nothing wrong with this, as long as a consensus is reached. What is important is collecting and tracking the thought process behind the decisions; this is for team-learning, not for criticism.

Some methods suggested for limiting the number of factor variations include:

1. **Limit Functional Requirement Variations:** As suggested by Dr. Emery, above, the design team can begin by agreeing to two designs, one that lies at the low end of the functional scale, one at the high end. Once the cost-effectiveness analysis has been completed using these two designs, the design team can compare the additional benefits gained from the high-end configuration to the incremental costs between the two configurations. Depending on the outcome of the comparison, management can decide if the marginal return on the additional expenditure is equal to, or greater than, the marginal return of the best use of the additional resources.
2. **Limit Timetable Variations:** The design team can agree to one initial timetable for implementing the various technical capabilities. Once a final configuration is agreed upon, the

implementation timetable can be re-evaluated to take advantage of any efficiencies offered by that particular configuration.

3. **Limit Technology Variations:** A standards-based target architecture was developed in Chapter 5. The design team must choose a transmission media (including the component configuration to implement it) and a network management system that provides the optimal migration path to reach the target architecture. The available alternatives for each of these will be ranked later in this chapter using FOM. However, certain alternatives may be ruled out early using known limitations, or initial cost data. Using the BACS as an example, we know that analog microwave will not meet our set requirements as a transmission media. With minimal research effort, some available network management applications may be ruled out, due to costs or for lack of required network troubleshooting features.

2. Specific Site Alternative Limitations

The physical sites involved in most telecommunications projects vary greatly. Some of these variations will limit the technical alternatives available at particular sites. For instance, suppose that cellular links are being considered as a major contender for system redundancy. However, we assume (or know) that cellular capability is not available at 10% of the sites. Rather than throwing this in as another variation, it would simplify the process if we complete the cost-effectiveness analysis before considering these specific variations. Once the cost-effectiveness analysis has ranked our technical alternatives, and cellular has been chosen, we can consider altering our plans for specific sites to overcome any limitations.

Limitations can affect scheduling, such as weather restricting site access to given times of the year. Other site limitations could include civil engineering aspects (e.g., building codes and restrictions, space, power), radio spectrum availability, utility access, and so forth. Unless these restrictions apply to a large percentage of the sites, they should be

considered after the initial cost-effectiveness analysis. The design team will have to decide the percentage of sites that must be affected before a restriction is allowed to effect the configuration used for the initial cost-effectiveness analysis.

C. COST EFFECTIVENESS ANALYSIS

1. Introduction

Many of the concepts presented in this section have been taken from the thesis of Cdr Robert Wilson [Ref. 28, Ch. 5-6].

The purpose of performing a cost effectiveness analysis (CEA) is to quantify the costs and effectiveness of network alternatives in a manner that allows the alternative with the best overall cost-effectiveness to be singled out.

> Cost-effectiveness relates to the measure of a system in terms of mission fulfillment (system effectiveness)... True cost-effectiveness is impossible to measure since there are many factors that influence the operation and support of a system that cannot realistically be quantified ... thus, it is common to employ specific cost-effectiveness *figures of merit* (FOM) ... to allow comparison of alternatives on the basis of the relative merits of each. [Ref. 36, p. 136]

Detailed definitions for costs and effectiveness will be given in sections 4 and 5.

The vast majority of CG telecommunications projects will have program costs of less than $30 million. Therefore, these projects will normally be categorized as "j III" (Ref. 29, p. 2] under the DOD project definitions and "Level IV" under the DOT project definitions. These project definitions allow the project managers to choose the tools they feel are best to implement a project of this size.

Although a CEA is not mandatory, it is a very effective tool and well worth the effort required. Application of CEA techniques assists the decision makers in quantifying any necessary tradeoffs and permits:

1. the various parties to a decision to comprehend the basis for each other's conclusions;
2. decision makers to draw on the intuitions and judgments of their staffs without abdicating their decision making prerogative;
3. sensitivity analyses to be made using variations in the estimates. [Ref. 30]

The CG COMDTINST M4150.2D, "Systems Acquisitions Manual," can be a great asset to use while planning and implementing even the relatively small Level IV projects. And if unexpected/uncontrollable problems crop up, making it impossible to meet schedule, technical, or cost projections, it will be reassuring to any project manager to be able to demonstrate every effort was made to anticipate problems beforehand.

2. CEA Overview

Many methods exist for completing a CEA. Some methods deal with the lack of tangible benefits better than others. The multi-attribute utility method used here was chosen because it measures system effectiveness without having to estimate monetary values for the intangible benefits provided by the system. It is very difficult to estimate intangible benefits for military telecommunications networks because no market value can be affixed to the final product. The essential steps of a CEA include:

1. define system objective;
2. identify essential mission requirements;
3. list alternatives;
4. state evaluation assumptions;

5. establish effectiveness measures;
6. evaluate alternatives' overall effectiveness;
7. develop cost data;
8. assess effectiveness and cost risks;
9. perform cost-effectiveness computations;
10. perform sensitivity analysis. [Ref. 31, 32, 33]

By using the structured approach model, the first three steps have already been accomplished. The next seven sections will deal with the remaining steps.

3. State Evaluation Assumptions

We do not know every detail of the actual demands that will be placed on a telecommunications system. Therefore, in certain areas we must make assumptions to fill in the missing details. For instance, do we know the actual availability requirements for the system? Generally not, but we can assume that anything less than, say, 99% availability could seriously lower our mission effectiveness. Anywhere that supporting data is not available an assumption must be made. However, assumptions should never be made blindly; the attribute should be researched and the assumption, along with the reasoning behind the conclusion, should be documented.

4. Establish Effectiveness Measures

To establish effectiveness measures, first we must define effectiveness. Hajek defines effectiveness as:

> ...a measure of the probability that the equipment will be ready and capable of performing its function and will not experience failure during its mission period. [Ref. 34, p. 219]

The functions that the equipment, or in our case network, is to perform have been spelled out in the requirements. We must now define what we mean by ready and capable. These are defined by using figures of merit (FOM), also referred to as objectives or criterion. For clarity, we will stick to FOM.

a. *Figures of Merit*

FOM are typically broad in scope. There are various techniques for generating FOM. Keeney and Raiffa [Ref. 35, p. 34] suggest starting at the overall objective and then begin asking questions. For instance, our overall objective for a telecommunications network could be stated as, "our objective is to provide a telecommunications network that will meet the users requirements and expectations in the most efficient manner possible." Now, the question would be, "what characteristics are necessary to meet our objective?" These characteristics, or FOM, would include [Ref. 35 for 1-4]:

1. *Reliability*: The probability that a system or product will perform in a satisfactory manner for a given period of time when used under specified operating conditions;
2. *Maintainability*: The ease, accuracy, safety, and economy in the performance of maintenance actions;
3. *Manability*: The human element and the interface(s) between the human and machine;
4. *Supportability*: The composite of all considerations necessary to assure the effective and economic support of a system throughout its programmed life-cycle;
5. *Interoperability*: The communications methods between machines that provide accurate and reliable access, interconnection, and transmission of data without affecting the applications that are running. [Ref. 8, vol. 4, p. F-9]

The various FOM will normally influence system effectiveness at different levels. To compensate for this, each FOM is weighted to equate its contribution.

By asking the question, "what do we mean by the FOM?," the FOM can be further broken down into more specific, measurable, areas known as *measures of* performance (MOP), sometimes referred to as attributes.

b. *Measures of Performance*

A MOP should be both comprehensive and measurable. A MOP is comprehensive if, by knowing the level of a MOP in a particular situation, the decision maker has a clear understanding of the extent that the associated FOM is achieved. A MOP is measurable if it is reasonable both (a) to obtain a probability distribution for each alternative over the possible levels of the MOP - or in extreme cases to assign a point value - and (b) to assess the decision maker's preferences for different possible levels of the MOP. For example, in terms of a utility function or in some circumstances, a rank ordering. [Ref. 35, p. 39]

Let's take the FOM "maintainability" as an example. What are the characteristics? Blanchard and Fabrycky state the most commonly used maintainability MOP include:

1. *Mean corrective maintenance time* (also known as, *mean time to repair*);
2. *Mean preventive maintenance time*;
3. *Median active corrective maintenance time*;
4. *Mean active maintenance time*;
5. *Maximum active corrective maintenance time*;
6. *Logistics delay time*;
7. *Administrative delay time*;

8. *Maintenance downtime*;

9. *Mean time between Maintenance*;

10. *Mean time between replacement.* [Ref. 36, p. 375]

Notice that some of the MOP listed above overlap (i.e., #4 = Average[#2 + #3]). The final set of MOP chosen for each FOM, however, must be non-redundant. Other desirable properties of the final set include complete, operational, minimal, decomposable (for definitions see Ref. 35, sec. 2.4.1].

Here again, the various MOP will normally affect the FOM at different levels. Therefore, each MOP is also weighted to equate its contribution to the FOM.

c. *Calculation of Overall Effectiveness*

Now that the FOM and MOP have been defined and assigned weights, overall effectiveness can be calculated. Table 11 is an example summary table of system effectiveness. Table 2 totals FOM values.

FOM values and effectiveness are calculated using the following equations:

$$FOMj = \frac{\sum_{1}^{i}(MOPiUtility * MOPiWeight)}{\sum_{1}^{i}(MOPiWeight)}$$

Equation 2: Figure of Merit Calculation

$$Effectiveness = \frac{\sum_{1}^{i}(FOMi * FOMiWeight)}{\sum_{1}^{i}(FOMiWeight)}$$

Equation 3: Effectiveness Calculation

Table 11: MOP Ratings and FOM Expected Values

ACCURACY	MOP Weight	Alter.#1	Alter. #2
Update Rate	4	5	6
Latency	4	5	4
Reference Sta.	2	5	5
ACCURACY Weighted: Total		**5**	**5**
AVAILABILITY	MOP Weight	Alter.#1	Alter. #2
Dependability	10	5	5
EMI Resistance	3	5	5
MP & Obs. Res.	2	5	3
Iono. Var. Res.	5	5	4
Graceful Degrad.	5	5	3
AVAILABILITY Weighted: Total		**5**	**4.24**
COVERAGE	MOP Weight	Alter.#1	Alter. #2
HHA/Coastal	10	5	5
Ocean Phase	5	5	5
Inland Waterway	5	5	9
COVERAGE Weighted: Total		**5**	**6**
INTEGRITY	MOP Weight	Alter.#1	Alter. #2
Timeliness	4	5	4
Index of Safety	6	5	5
INTEGRITY Weighted: Total		**5**	**6**
ADAPTABILITY	MOP Weight	Alter.#1	Alter. #2
International	3	5	3
Interagency	3	5	7
Technical Flex.	6	5	7
Open Sys. Int.	3	5	5
Spectral Eff.	6	5	5
Institutional	6	5	3
ADAPTABILITY Weighted: Total		**5**	**5**

Table 12: Total Weighted FOM Effectiveness Example

FOM	FOM Weight	Alter.#1 Exp. Value	Alter. #2 Exp. Value
ACCURACY WTed	5	5	5
AVAILABILITY WTed	10	5	4.24
COVERAGE WTed	5	5	6
INTEGRITY WTed	10	5	4.6
ADAPTABILITY WTed	10	5	5
OVERALL WTed Effectiveness		5	5

5. Develop Cost Data

Two of the main factors that affect project costs are the system elements (including support) and the project schedule. To provide accurate estimations, the system elements must be broken down to a detailed level and include the total life-cycle costs. The schedule will affect cost estimations depending on the demand it places on resources and due to the time-value of money.

a. *Estimating Tools*

Many tools exist that can help us detail both system elements and project schedules. Two of the more important tools include the Work Breakdown Structure (WBS) and the Program Evaluation and Review Technique (PERT).

The WBS gives us a components view. It is used to break complex systems down into subsystem and component levels that can more easily be evaluated. A simplified example of a WBS can be seen in Figure 22. Each WBS element represents an identifiable item of hardware, software, data set, or service [Ref. 37, Encl. 3, p. 2]. Each "level" breaks the associated WBS element into smaller, more detailed elements.

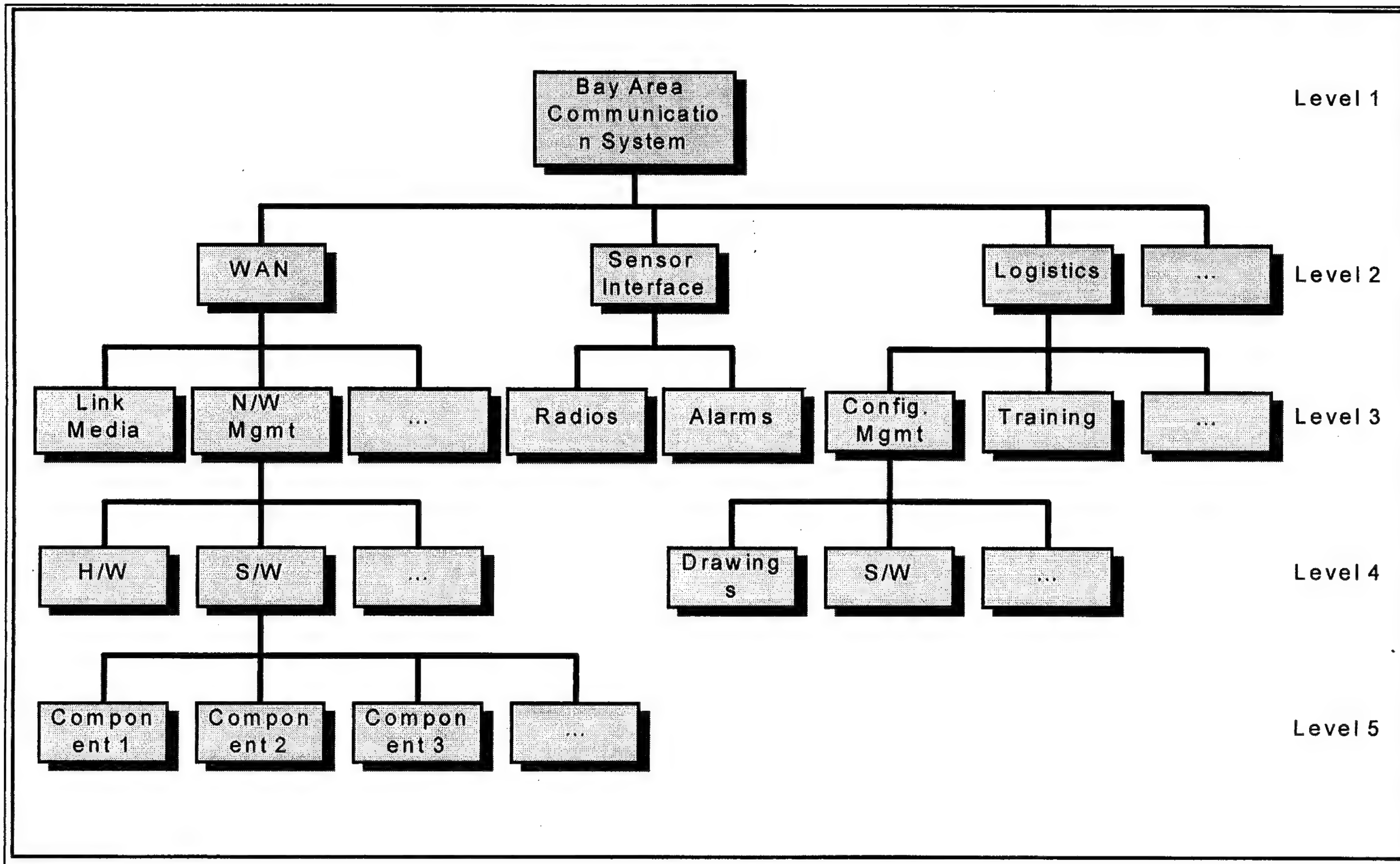


Figure 22: Work Breakdown Structure Example

The PERT assists project organizing and estimating from an activities perspective. This tool helps us in the following areas:

1. **Define the Activities**. Tasks to be performed.
2. **Define Activity Relationships**. Identify predecessor/successor and lead/lag relationships (finish to start, start to start, and finish to finish) among tasks.
3. **Obtain Time Estimates**. Estimate the time (duration) necessary to perform each activity.
4. **Incorporate External Constraints**. Determine schedule constraints such as mandatory completion dates, intermediate milestone dates, contractual delivery dates, or interfaces with other projects.
5. **Incorporate Resources Data**. Apply constraints on availability or resources such as labor, material, equipment, machines, and funds to develop a feasible network that can be achieved within resource limitations.
6. **Establish a Baseline Schedule**. Assign specific calendar dates to activities (and their resources) and issue as a baseline work plan. Identify activities on the critical path. The baseline schedule must be consistent with the technical and project baseline.
7. **Planning the Schedule**. The project manager should identify and schedule near-term tasks (those to be performed within 12-18 months) in more detail and long term tasks ... in lesser detail. [Ref. 37, encl. 3, p. 8]

b. *Life-Cycle Costs*

Each alternative's cost data must be based on its total life-cycle costs. As mentioned before, if a telecommunications network is planned correctly, there should seldom be a reason to scrap the whole thing and replace it all at once. However, the equipment components that make up a telecommunications network pass through four stages during their life-cycle. These stages, and some of the costs associated with the stages, are shown in Table 13. If only a portion of a

telecommunications network is being replaced, then only the life-cycle costs for the alternative sections need be compared, including those costs which vary with each alternative (i.e., support, training, etc.).

Table 13: Life-Cycle Stages & Cost Elements

RESEARCH & DEVELOPMENT	PRODUCTION & CONSTRUCTION	OPERATIONS	SALVAGE & DISPOSAL
* Planning	* Production	* Personnel	* Inventory Close-out
* Management	* Planning	* Consumables	* Shipping
* Engineering	* Management	* Facilities	* Data Mgmt
* Testing	* Initial Spares	* Support	* Refurbishing
* Evaluation	* Training	* Maintenance	* Waste Mgmt
* Equipment	* Support Equip.	* Shipping	
* Facilities	* Manuals	* Technical Data	
	* Testing	* Supply Mgmt	
	* Engineering	* Modification	
	* Facilities	* Training	
	* Support Facilities		
	* Initial Transport		

c. *Present Value Costs*

To complete the CEA, all costs throughout the life-cycle must be discounted back to their present values in order to view the alternatives on an equivalent basis. The present value of yearly costs can be computed using the equation for present value, as shown in

Equation 4. A discounted rate of 7%, as set by the Office of Management and Budget (OMB) in Circular No. A-94, should be used.[5]

$$PV = F\frac{1}{(1+r)^t}$$

Where, PV = present value for year t
F = future value
r = interest rate
t = number of years from present

Equation 4: Present Value Calculation for Year t

For example, to compute the present value for the costs of a network with a 12 year life-cycle, Equation 5 would be used.

$$PV = F_1\frac{1}{(1+r)^1} + F_2\frac{1}{(1+r)^2} + F_3\frac{1}{(1+r)^3} \ldots + F_{12}\frac{1}{(1+r)^{12}}$$

Where, PV = present value for year t
F = future value
r = interest rate (0.07)

Equation 5: Example Equation for 12 Year Life-Cycle

While determining the life-cycle costs, we should try to be as thorough as possible; however, we must also take care not to include redundant costs in more than one category.

d. *Estimating Pitfalls*

Once the estimating process is about complete, project managers, even seasoned managers with a few projects under their belts,

[5] This discount rate was last updated January, 1995. It is revised when significant changes in interest rates occur.

should take the time to review the estimating process. Hajek's list of cost estimating pitfalls to avoid is shown in Figure 22.

Cost Estimating Pitfalls

1. *Omissions*: Was any significant cost element forgotten? For instance, are there any bench checks planned and does the estimate include the engineering, material, and other costs for such effort?
2. *Inaccuracy of* the *work breakdown*: Does the work breakdown adequately account for all the subsystems and efforts required of the device?
3. *Misinterpretation of the equipment data or function*: Is the interpretation of the complexity of the device accurate? Interpretations leading to excesses of complexity, or simplicity, will result in estimates that are either too high or too low.
4. *Use of wrong estimating techniques*: The correct estimating techniques must be applied to the device in question. For instance, the use of cost statistics derived from production runs of a similar subsystem and using such figures for a prototype device which requires engineering and/or development will invariably lead to excessively low estimates.
5. *Failure to identify and concentrate on major cost elements*: It has been statistically established that for any piece of equipment (or system), 20 percent of the subsystems will account for 80 percent of the total cost (Pareto's Law of Distribution). The point is that project engineers should concentrate their time and effort on the high-cost subsystems in order to enhance their chances for establishing an accurate cost estimate.
6. *Failure to assess and provide for risks*: By its nature a prototype device involves engineering and design effort that must be breadboarded and bench tested for verification. Such tests usually involve an expenditure of effort to redesign and refine.

Figure 23: Cost Estimating Pitfalls [Ref. 34, p. 62]

(i)

6. Risk Assessment

Proper project management requires that we evaluate what impact our decisions may have on increasing or decreasing the chance, or risk, that future problems will occur. This section will discuss the different perspectives of risks, the elements of risk, and the analysis of risk.

a. *The Three Perspectives of Risk*

There are three perspectives to risk, all of which must be considered to fully comprehend the effects an element of risk may have on a project. The three perspectives are:

1. potential magnitude of loss (how much we may lose);
2. chance of loss (probability of a loss occurring);
3. exposure to loss (how much can we afford to lose). [Ref. 38, p. 24]

For instance, suppose we identify the schedule for microwave installation as containing an element of risk. If we stay with the currently planned installation crews, there is a chance that the schedule could be affected by winter weather. If we increase the crew size, project costs will increase. We must consider it from the three perspectives: 1) how much time may we lose?, 2) what chance is there the schedule will be delayed (very slim/very great)?, 3) if the loss occurs, can we afford it? If any of the three components are at levels that cannot be accepted, we must find a way to decrease the risk.

b. *The Elements of Risk*

The Defense Management Systems College Publication, "Risk Management, Concepts, and Guidance," identifies five elements of risk: Cost, Schedule, Technical Performance, Programmatic, and Supportability. The first three are defined as basic elements. Table 14 contains some of the sources for the five risk element. Each of the applicable elements should be evaluated using the three perspectives.

c. *Risk Analysis*

Risk analysis must be completed for both life-cycle costs and effectiveness values.

During this phase of the project (alternative selection), the risks affecting life-cycle costs should be estimated in dollars for comparison purposes. The affects of these risks can normally be estimated in either personnel or equipment costs. With a little effort, these can be culminated into a final monetary estimation. These costs are normally stated with a plus/minus percentage, where the value falls within two sigma (95% confidence interval).

Table 14: Sample Risks by Element

Typical Technical Risk Sources	Typical Programmatic Risk Sources	Typical Supportability Risk Sources	Typical Cost Risk Sources	Typical Schedule Risk Sources
Physical properties	Material Availability	Reliability & Maintainability	Sensitivity to:	Sensitivity to:
Material Properties	Personnel Availability	Training & Training Equip.	Technical Risk	Technical Risk
Radiation Properties	Personnel Skills	Operation & Support Equip.	Programmatic Risk	Programmatic Risk
Testing/Modeling	Safety	Manpower Considerations	Supportability Risk	Supportability Risk
Integration/Interface	Environmental Impact	Facility Considerations	Schedule Risk	Degree of Concurrence
Software Design	Communication Problems	Interoperability Considerations	Overhead/G&A Rates	Number of Critical Path Items
Safety	Labor Problems	Transportability	Estimating Error	Estimating Error
Requirement Changes	Requirement Changes	System Safety		
Fault Detection	Political Advocacy	Technical Data		
Operating Environment	Contractor Stability	Computer Resources Support		
Proven/Unproved Technology	Funding Profile	Supply Support		
System Complexity	Regulatory Changes	Maintenance Concept Changes		
Unique/Special Resources				

Analyzing risks on the effectiveness side, and then converting them into monetary values, or other scaleable values, is a different story. In some cases, with a lot of work, experience, and skill, this is may be possible; however, in most cases it is not. The very act of converting these estimated risk values into a single value suggests a much higher level of accuracy than is available. suppose an analysis has been completed and the risk converted into a value of $48,000 ± 20%. Once given to the decision-makers, the first questions asked will include:

1. what is the basis for these values?
2. What certainties are the estimates based on? What uncertainties?
3. Has the methodology used been proven accurate in the past? How accurate? Were the conditions similar?

These are difficult questions to answer, let alone defend; but if a decision-maker is going to make informed decisions and be held accountable for these decisions, they need to understand where the figures came from.

Another alternative, as explained by Dr. James Emery[6], appears to be much more appropriate, as well as convenient. He states that if the decision-makers are going to make the decisions, their real need is the information on which to base those decisions. He suggests documenting the applicable information in a concise paragraph form, along with the analyst's perspective of the situation. In this manner, the decision-makers are supplied with all the pertinent data and can decide for themselves what the possible levels of risk will be.

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[6] As per conversation with Professor Emery on December 6, 1995.

7. Cost Effectiveness Computations

Once the effectiveness, life-cycle costs, and monetary risk values have been calculated, a cost-effectiveness summary table can be formed. Table 15 is an example of such a table.

Table 15: Cost Effectiveness Summary Table

	Alternative # 1	**Alternative #2**
Overall Effectiveness	5.0	4.835
Life-Cycle Costs ($K)	109,148	190,290
Cost Risk	± 21,830	± 47,572

8. Sensitivity Analysis

Suppose the analyst has completed a CEA and the final numbers show alternate "X" to be the most cost-efficient. To complete this CEA, we have had to make assumptions, estimate costs, estimate usage, and make a host of other educated guesses, all of which affect the outcome of the final numbers.

The purpose of the sensitivity analysis is to help us understand just how sensitive our final numbers are to relatively small changes in our assumptions and estimates. To measure sensitivity, normally only one variable is changed at a time and the effects measured and recorded; however, if a variable that has other variables dependent on it is changed, then all of the dependent variable values should be changed as well. For example, if "per hour" leased-line charges vary with usage, then the values for both usage and "per hour charges" should be varied at the same time. Sensitivity analyses can be used to measure the effects of both controllable and uncontrollable input variables.

With the advent of modern spreadsheet products, a sensitivity analysis can be completed very quickly. It is recommended that all CEA computations be completed using a worksheet application.

D. THE BACS MIGRATION

With the wide range of site types, site locations, site telecommunications requirements, and the like, the final network will most likely use several types of transmission media. For example, some sites already have leased lines installed. The requirements for some of these sites will never rise above the service already provided. Therefore, there is no reason to replace these links with different technology.

On the other hand, some remote sites now operating over microwave require redundancy. Even if microwave is found to be the most cost-efficient technology for these sites, a secondary technology will likely be required for the redundancy. This example shows the extent to which the standards, applications, and components chosen must be kept vendor and technology-independent for as long as possible.

The biggest challenge with using a CEA with the BACS project could possibly be limiting the number of alternative migration candidates to be considered. The project managers must find a method to limit candidates without excluding those that could end up being the best alternatives.

E. CONCLUSION

The CEA is a very useful tool. It provides the organizational procedures to insure that our estimations are as concise as possible. One must remember, however, that it is only a tool; and the quality of the final product depends as much on the craftsman and the material (data) used, as it does on the tool.

VIII. SUMMARY

Before summarizing the phases discussed in this paper, let's discuss the last two phases, "Implement System Plan," and "Maintain System Process." By excluding them from the content of this paper in no way suggests they are less important than the others. In fact, the first six phases only build the solid foundation on which the actual project, contained in the last two phases, is built.

The procedures used during the Implement System Plan phase will vary greatly depending on the cost, schedule, type of contract, and many other variables. However, if the previous five phases have been completed judiciously, the project officer should be aware of all the processes necessary for a successful implementation. The last phase, "Maintain System Process," adds an additional dimension in which the CG has not operated in the past. There are two main themes behind this phase. One is to continue the migration process, upgrading the architecture as necessary. It is only due to the recent advances in technology that we are now able to incrementally upgrade networks. The second theme is based on periodically re-evaluating the network. The TAFIM emphasizes that this should be done by reiterating the other six phases of the model.

Although the procedures in this paper are laid out in a 1-2-3 fashion, it should be understood that numerous iterations of portions of the model may be necessary before reaching a level of acceptance by all parties involved. Although this can be time consuming and must be limited in some manner, it does lead to a better designed product.

The BACS Replacement Project is relatively simple from a technological view. However, from a functional or organizational perspective, the project will be very complex. Gathering, evaluating, and tracking the functional requirements of at least 11 different entities located at 18 different sites will not be easy. This provides the design team with a great temptation to aggregate details to simplify the problem. By using the Structured Approach Model, the design team will be encouraged to view the project from various perspectives and use either the procedures suggested in this paper, or alternative methods for tracking and documenting all the pertinent details.

For an organization to become more efficient and effective as a whole, it must learn to apply systems thinking. Procedures and reward systems must be changed to encourage individuals to plan for efficiency and effectiveness on the organizational level, rather than the department, division, or command level.

The Structured Approach Model is one method for applying systems thinking to project management. It ensures that the project is planned on an organizational level, taking into account the requirements and resources of all the entities involved. By examining each of the seven phases from the functional, organizational, and physical views, the prospect that important details will be overlooked greatly decreases. By investing the additional time up front necessary to apply the Structured Approach Model, the project team will be steered towards a network that will benefit the total organization. The network itself will be designed for greater interoperability, supportability, as well as cost and technical performance.

The Coast Guard must have an effective, interoperable telecommunications backbone if its overall efficiency and effectiveness is to increase.

GLOSSARY

Access control server - The access control server maintains the access control lists for each object within the technical environment. The access control server determines whether access to the requested system object is authorized.

Applications server - An application server provides a set of standard application services to clients. It is a form of packaging an application as a commonly used and reusable component of the infrastructure.

Authentication server - Validation of users, nodes, programs, and other required objects is performed through the authentication server. Secure channels using encryption and/or some form of trusted communications provide the linkage between client and server.

Batch processing - Batch processing environments are characterized by their ability to queue work (jobs) and manage the sequencing of processing based on job control commands and lists of input data. The results of this processing include updated information files or databases and often printed reports or special forms that are themselves queued as output jobs.

Broadcast - Broadcasting environments provide one-way audio or audio/video communications between a sending location and multiple receiving locations. They include the use of private TV facilities that can be purchased or leased for corporate purposes. Many organizations are taking advantage of these facilities and offsetting travel costs for use in corporate announcements and product introductions.

Communications management services - Communications management services is another GTE that is used by all of the other GTE that want to communicate. This environment implements the communications infrastructure consisting of various communication servers, name and directory services for resolving addresses, and authentication and access control for ensuring the appropriate level of security. Thus, all the technology associated with communications and connectivity is bundled into this environment.

Communications server - The communications server forms the basis of managing connections between objects in the environment. It provides connections between objects independent of the physical implementation of the network and ensures accurate delivery of messages between objects.

Computer conferencing - Computer conferencing environments combine the merits of document creation, E-mail, and conferencing by allowing groups and subgroups to participate in "conferences" via computer workstation. These conferences, however, do not occur in real time. The conferees discuss proposed topics through interacting over time. Conferees, or invited guests, can drop in or out of conferences or subconferences at will. The ability to trace the exchanges is provided.

Conferencing management services - Conferencing Management Services supports the real-time exchange of information from one or more user clients. It permits a user to address a communication to any member of a group without needing to know exactly who is in the group receive communications from all or selected members of the group without needing to know who is currently in the group, and to reply to them in a like manner.

Cryptographic server - Encryption services for any process are provided by the cryptographic server. The cryptographic server also manages keys and handles distribution of valid keys among the cryptographic servers. A centralized key management server may be required.

Data server - The data server provides data services to clients. A client will send a request to a data server (sometimes called a data*base* server) and the server will respond with the results of the request. The accessing and updating of the data maintained on the data server is performed by the data server, not by the clients.

Database management services - Database management services consist of the servers required for managing files and data within the technology environment. It consists of data servers that implement databases and file servers that provide local and remote access to various types of files.

Decision support - Decision support environments provide interactive modeling and simulation tools that allow the user to analyze the effects of alternative decisions. These modeling and

simulation tools typically work in conjunction with files and databases that were created from batch or transaction processing environments.

Desktop or Portable Intelligent Workstations - These serve single users and provide personal computing services and access to network(s).

Development services - Development services provide support for all aspects of systems delivery including all phases of the development life-cycle, prototyping, and end user development. This environment interacts with the other GTE to access information on the current infrastructure and to implement changes and enhancements.

Directory server - The directory server provides a means of finding a set of entity attributes based on qualifiers, such as a telephone number or other descriptive characteristic. Unlike a name server, the searches are often ambiguous and based on a combination of attributes.

Distribution management services - Distribution management services support the distribution of messages, transactions, files, and any other information between technology environments and physical locations. This environment consists of servers that implement electronic mail, voice mail, and EDI. It also is tightly linked to the communications management services GTE to provide the actual communications between components.

Divisional or Departmental Processing Systems - These provide, primarily local users, on-line transaction processing services.

Document management services - Document management services are analogous to information management services, providing other environments with the means to access and manipulate documents—either text only or some combination of data, text, voice, graphics, and image (a compound document). The key difference between these two technology environments today is the level at which we can manipulate basic elements of information. In information management services, we can access and manipulate each field within the file or database. In document management services, we generally access the entire file or document using application specific formats for manipulating portions of the document. For example, the format for a Microsoft Word

document is different from WordPerfect; likewise, the way graphics is stored in each differs.

Document processing - Document processing environments extend the basic capabilities of text processing to take advantage of the graphics capabilities of today's workstations and laser printers. Consequently, they provide powerful document and presentation tools for the end user.

Document storage & retrieval - Document storage and retrieval environments are used to retain large volumes of stored information in document formats. Originally these systems were based on microfilm media using film or fiche with special readers to magnify the information. Computer output microfilm (COM) systems are used to store computer-generated listings or reports.

EDI translation server - The EDI translation server interprets the content of EDI messages and routes them to the appropriate EDI partners. The EDI server works hand in hand with the mail server but needs to interpret the EDI message to translate it or route it to the correct recipient.

Electronic mail - Electronic mail environments support the storage and forwarding of directed messages, mail, and other documents or files between sender and one or more recipients. They provide the sender with facilities to create or define the message(s) or file(s) to be sent, use directories and distribution lists for routing information, assign priorities, use pre-formatted electronic forms, and trace the status of messages sent.

Electronic publishing - Electronic publishing environments extend document creation and production tools to provide formal publishing capabilities. This includes incorporation of photographic quality images and color graphics, very advanced formatting and style features, such as wrapping text around graphic objects or pictures, and kerning (overlapping characters to optimize spacing).

Enhanced telephony - Enhanced telephony environments provide improved means of using the phone system for interactive audio exchanges between users. Features include call forwarding, call waiting, programmed directories, teleconferencing capability, automatic call distribution (useful for busy customer service areas), and call detail recording.

Enterprise or Corporate Processing Systems - These serve a large base of networked users with on-line and batch processing services.

Establishment-based Switching Systems - Premise-based switching services Gateways to WAN Associated servers (e.g., IVR, V-Mail).

Expert systems - Expert systems environments use a type of artificial intelligence built with inference engines and knowledge or rule bases that take or recommend actions based on presented situations and past "experience." They are used to augment human decision-making processes where the "expertise" or thought processes of the decision maker can be defined as rules.

File server - The file server provides transparent access to files from workstations and other clients. Unlike a data server, the file server provides access and linkages to the file directories and is not aware of the contents of the file. Processing of contents of a file needs to be performed by the client. The file server does no client-visible manipulation of the data within a file. Essentially, the file server provides the client with the use of a virtual disk drive and little else. For example, in a workstation environment, the workstation would perform all the processing on the file.

Hypermedia - An emerging area for information management is hypermedia. Hypermedia provides a highly flexible way of linking objects. Over time, documents, images, and other objects could be linked in hypermedia databases resulting in the elimination of document management services as a separate entity.

Hypermedia processing - Hypermedia processing is a new environment that extends the object-oriented approach to organizing and displaying information by utilizing various relationships between the stored or created objects. As such, it overcomes the limitation of the printed page and allows the user to "navigate" through the compiled information based on mixed form objects in a manner that is consistent with the needs and capabilities of the user, not some fixed presentation format.

Inquiry processing - Inquiry processing environments support functional area activities requiring interactive selection, extraction, and formatting of stored information from files and databases. They are used in conjunction with batch and transaction processing environments to provide information retrieval using

either structured (routine) or ad hoc (definable) queries. They are intended to replace the need for extensive reporting systems by providing only needed information on demand.

Intelligent Wide Area Network Systems - A WAN system capable of providing value-added WAN switching services, transparent access to servers, and WAN management.

Local Area Network Systems (LAN's)- LAN's connect file servers and device servers and provide for local transport and resource sharing.

Mail server - The mail server provides mail transfer capabilities for a community of users. The basic function is to support the store and forward of interpersonal messages between users. The mail server moves messages based on the contents of the *message envelope* not the message's contents.

Name server - The name server provides a means of finding an attribute of an entity given the unique name for any entity within the technology environment. Entities can be physical components (computers, workstations, network nodes), logical components (application modules, data storage locations), or users.

Presentation server - The presentation server provides presentation services for a client application and/or a person. It creates a generic presentation environment that is independent of the underlying technology and provides a means for users to interact with the technology environment.

Print server - The print server provides common printing services to clients within the environment. The print server provides transparency between the client and the physical printer. For example, differences between different vendors' laser printers should be transparent to the client.

Real-time control - Real-time control environments support event-driven processes supporting monitoring and actuation of physical processes. For this reason, they are often referred to as sensor-based systems. They are designed to handle and process interrupts from a variety of sources (typically involving some kind of sensor device or timer), process associated information through some type of capture or control algorithm, and respond, if necessary, with an appropriate signal to a control or actuation device.

Repositories for system construction - A passive repository, such as those being introduced by IBM, DEC, and others, can provide the dictionaries and system encyclopedias needed for defining and constructing application systems and data. This type of repository is the essential underpinning of a CASE environment, as it provides the basis for storing information at each phase in the development cycle and transferring that information from one phase to another.

Repositories for systems management - Another type of repository, called the active repository, can be used to store system information and to dynamically manage the IT environment. For example, with the capabilities of an active repository, system management services could manage the execution of applications to optimize performance and reliability.

Repository services - Repository services is an emerging GTE that will provide the repository environment for managing the technology environment and the applications and data stored in the environment. The repository can store information about any "object" in the technology environment including, but not limited to, the physical processors, application modules, data, and processing functions. All of the GAE, GTE, components, and servers defined in this document would be entities in a repository.

Sensor monitor/actuator server - The sensor monitor/actuator server provides client applications and users with an interface to physical devices such as cash dispensers, building monitoring systems, or any other device that interacts with physical control systems.

Shared screen teleconferencing - Shared screen teleconferencing environments are another newly emerging type of system aimed at supporting more effective remote communications in an interactive mode between two or more users. They combine an audio teleconferencing capability with shared common workstation "windows" that are refreshed on every conferee's workstation whenever someone displays new material or changes an existing display.

System management services - System management services support all activities dealing with the management of the computing environment, interacting with all other GTE to provide

the management capability to monitor and control the total environment.

"T" or "t" - Designation used to represent the Coast Guard's Command, Control, and Communications community. Capital t represents headquarters staff, while the small t represents "t'" personnel assigned to other commands.

Text processing - Text processing environments support the creation of text documents. They have evolved from the early word processing systems of the seventies to be popularized as part of the explosive application growth of desktop personal computers. They offer greatly improved editing and revision capabilities over the typewriters that they were designed to replace.

Time server - A critical need in distributed environments is to make sure that time is synchronized throughout the environment. This is especially important in distributed transaction processing applications and database environments where logs need to be kept synchronized to support transaction backout and recovery.

Transaction media services - Transaction management services implement the environment required for managing transaction processing. This environment includes the basic functionality and servers required to implement a transaction processing application. In today's world, CICS would fit under transaction management services. In the future, it is anticipated that a client/server environment will become the norm.

Transaction processing - Transaction processing environments support on-line capture and processing of information in an interactive exchange with the user. These typically involve predetermined sequences of data entry, validation, display, and update or inquiry against a file or database.

User interface services - User interface services provide the basic means for users to interact with the computing environment, managing the user interface for any class of user interface device from a simple character terminal to an advanced graphic workstation. User interface services also provide support for the user in navigating through to the appropriate system or server, authenticating the user and managing the user's desktop.

Video processing - Video processing environments support the creation of video "productions," either as sequential presentations

or as interactive presentations, under user control. They involve both video and sound capture and editing, as well as incorporating still graphics and title generation capabilities.

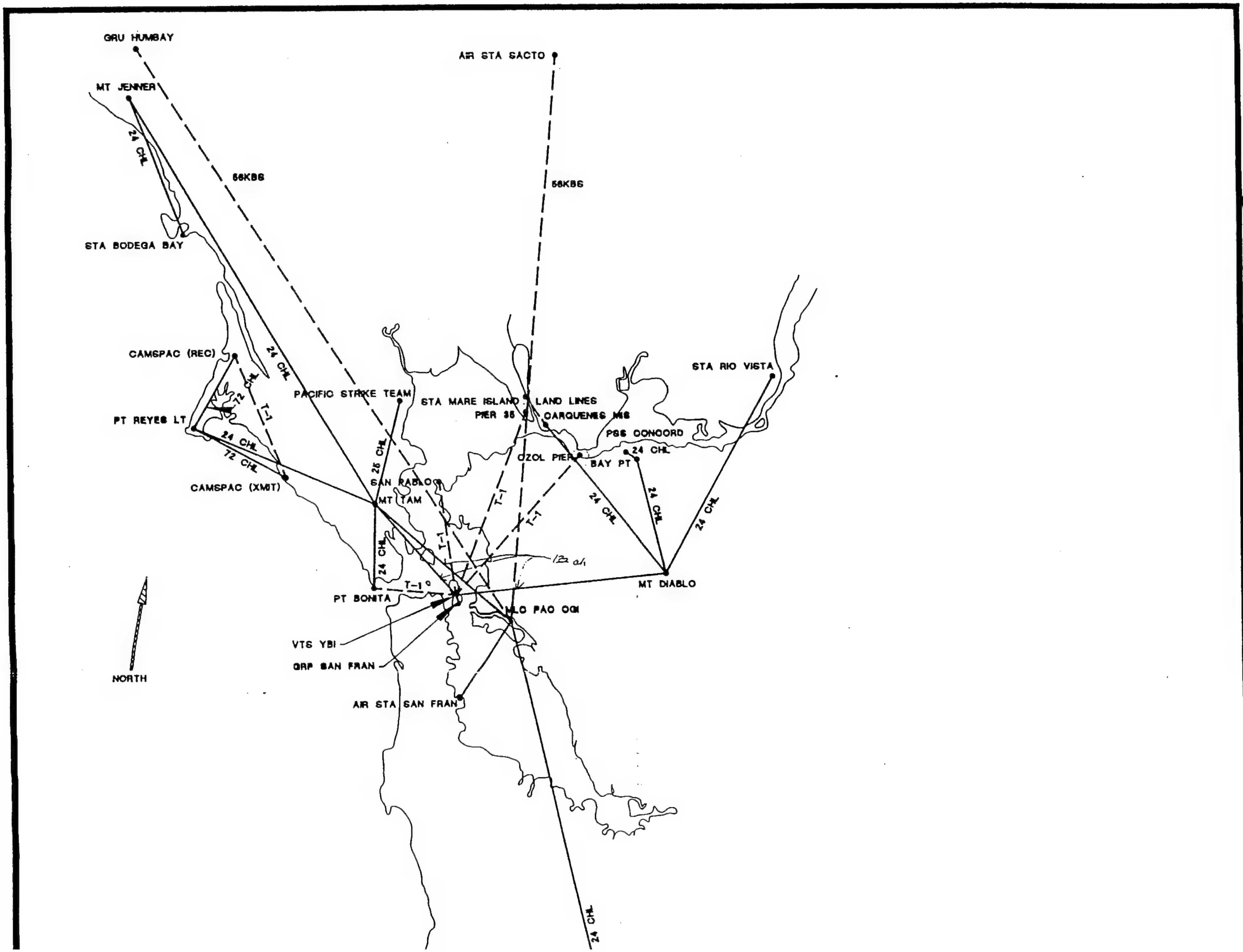
Video teleconferencing - Video teleconferencing extends the remote meeting environment to include full motion display of events and participants in a bi-directional manner. Thus, the facial expressions and body language of presenters and questioners is displayable to all participants in a conference.

Voice mail - Voice mail environments offer the storage and forwarding of voice messages for a designated set of recipients. They are usually used as an extension of the phone system to provide an alternate to message centers. They typically allow the recipient to retrieve recorded messages remotely from any touch-tone telephone.

APPENDIX A:

BACS SITE LOCATION CHART

1


GRU HUMBAY
AIR STA SACTO
MT JENNER
56KBS
56KBS
24 CHL
STA BODEGA BAY
24 CHL
CAMSPAC (REC)
72 CHL
T-1
PACIFIC STRIKE TEAM
STA MARE ISLAND
LAND LINES
PIER 35
CARQUENES MS
STA RIO VISTA
PT REYES LT
24 CHL
72 CHL
PSS CONCORD
24 CHL
OZOL PIER
BAY PT
25 CHL
SAN PABLO
CAMSPAC (XMIT)
MT TAM
T-1
T-1
24 CHL
24 CHL
24 CHL
T-1
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MT DIABLO
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VTS YBI
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NORTH
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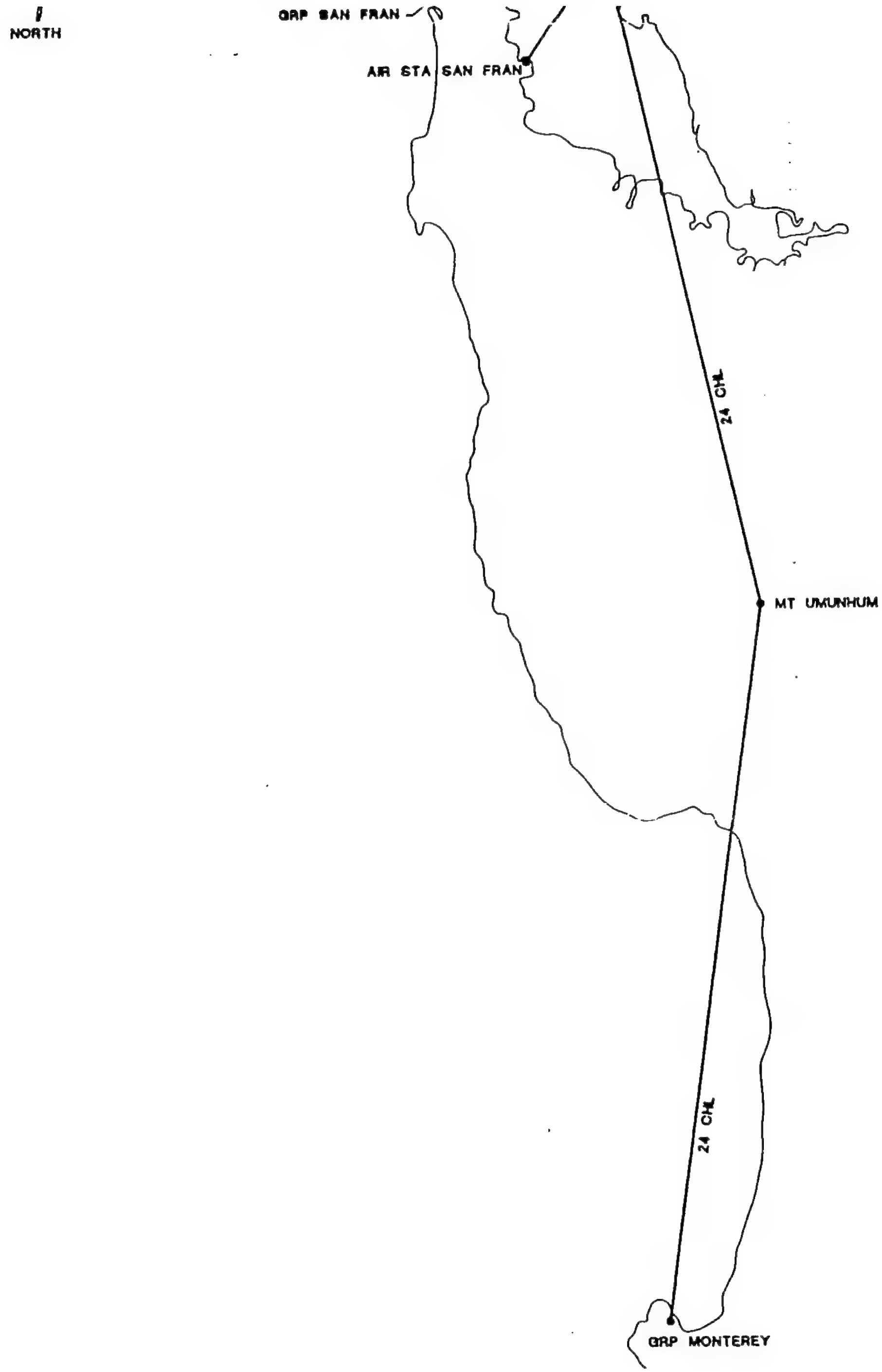


TTS-2

DESIGNER

DRAFTER
T.ERDMAN

CHECKER

APPROVED:
MR.JOE THOMPSON
PROJECT MANAGER

TECHNICAL ASSISTANT

UNITED STATES COAST GUARD ALAMEDA, CA.
MAINTENANCE & LOGISTICS COMMAND PACIFIC
COMMAND, CONTROL & COMMUNICATIONS

BACS REDESIGN
COMMUNICATIONS SYSTEM

APPROVED: DATE:
CAPT R.F. CARLSON
CHIEF OF BRANCH

MR. JIM COTE'
SECTION CHIEF

DRAWING NUMBER
MLC PAC-257

REV.

SCALE: NONE

SHEET 1 OF 1

'A' SIZE

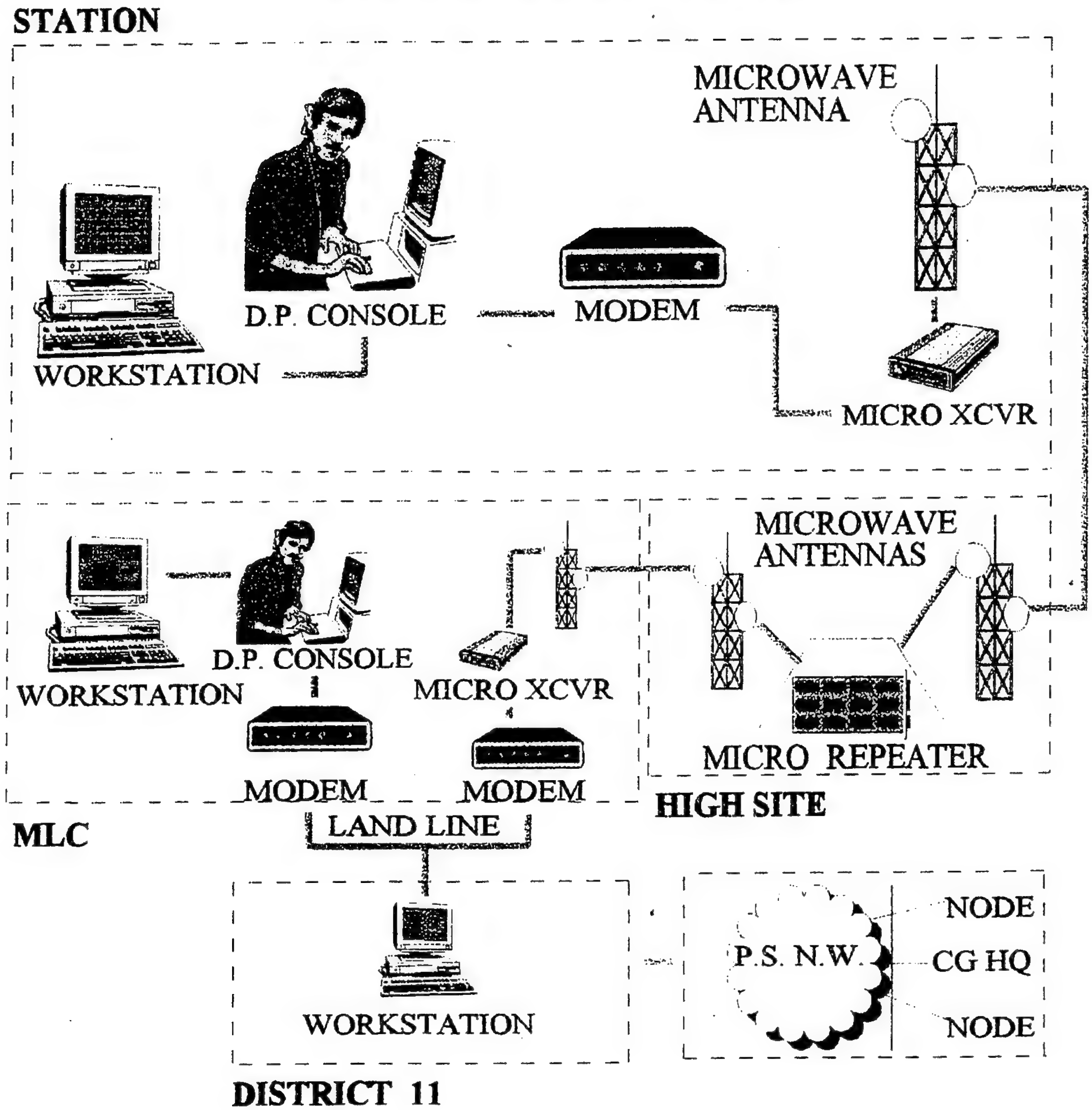
MLCP-257_SHT

148

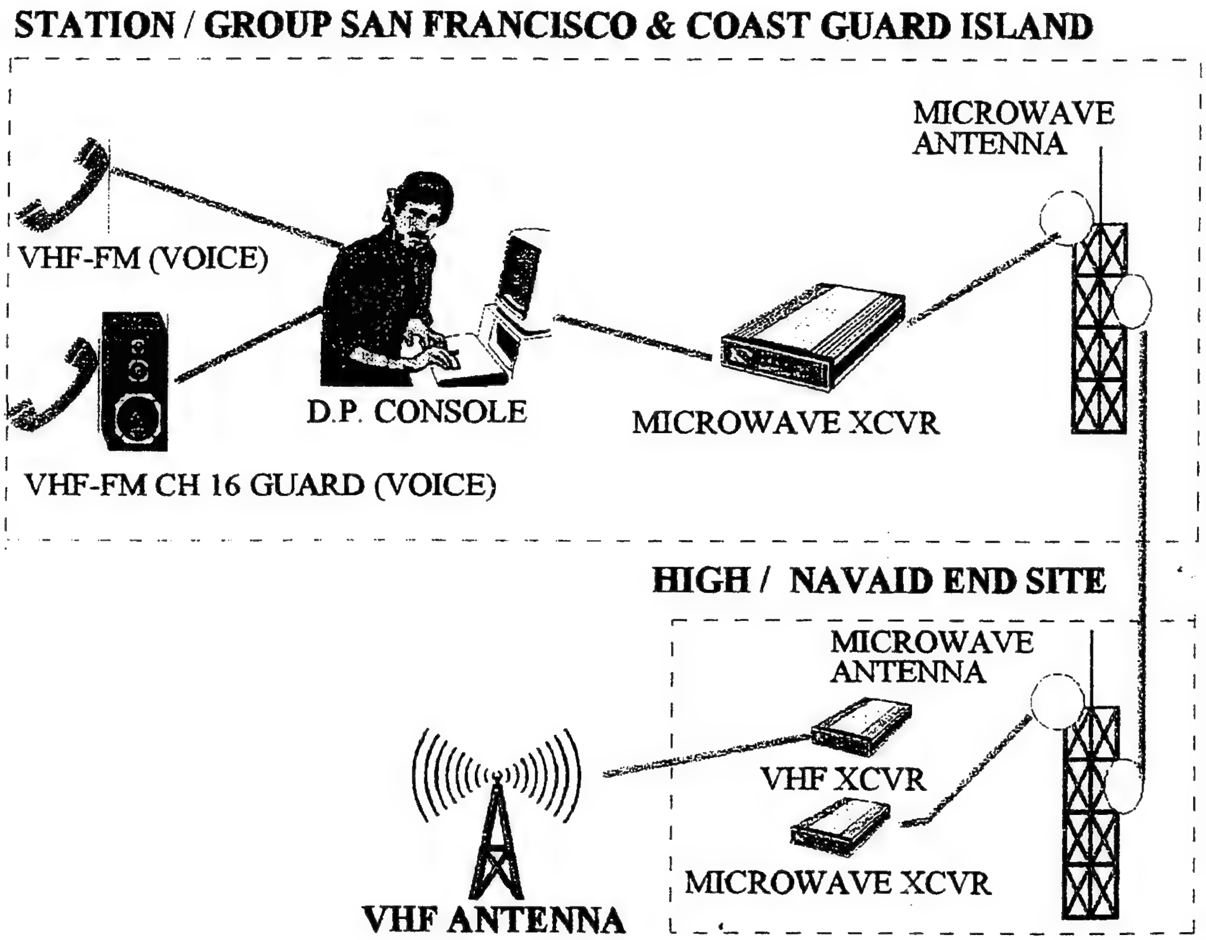
APPENDIX B:

SYSTEM FUNCTIONALITY BLOCK DIAGRAMS

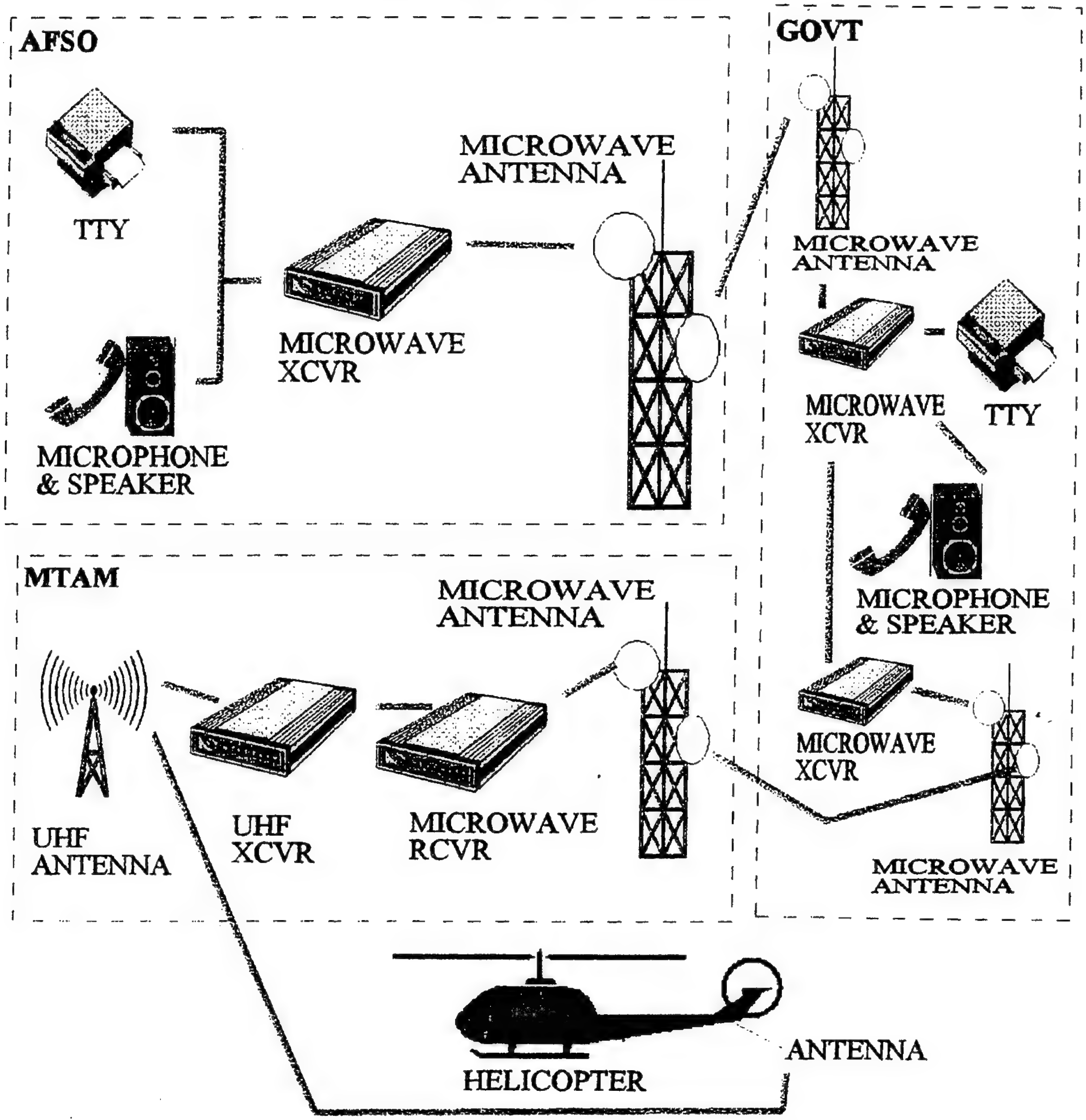
COAST GUARD DATA NETWORK



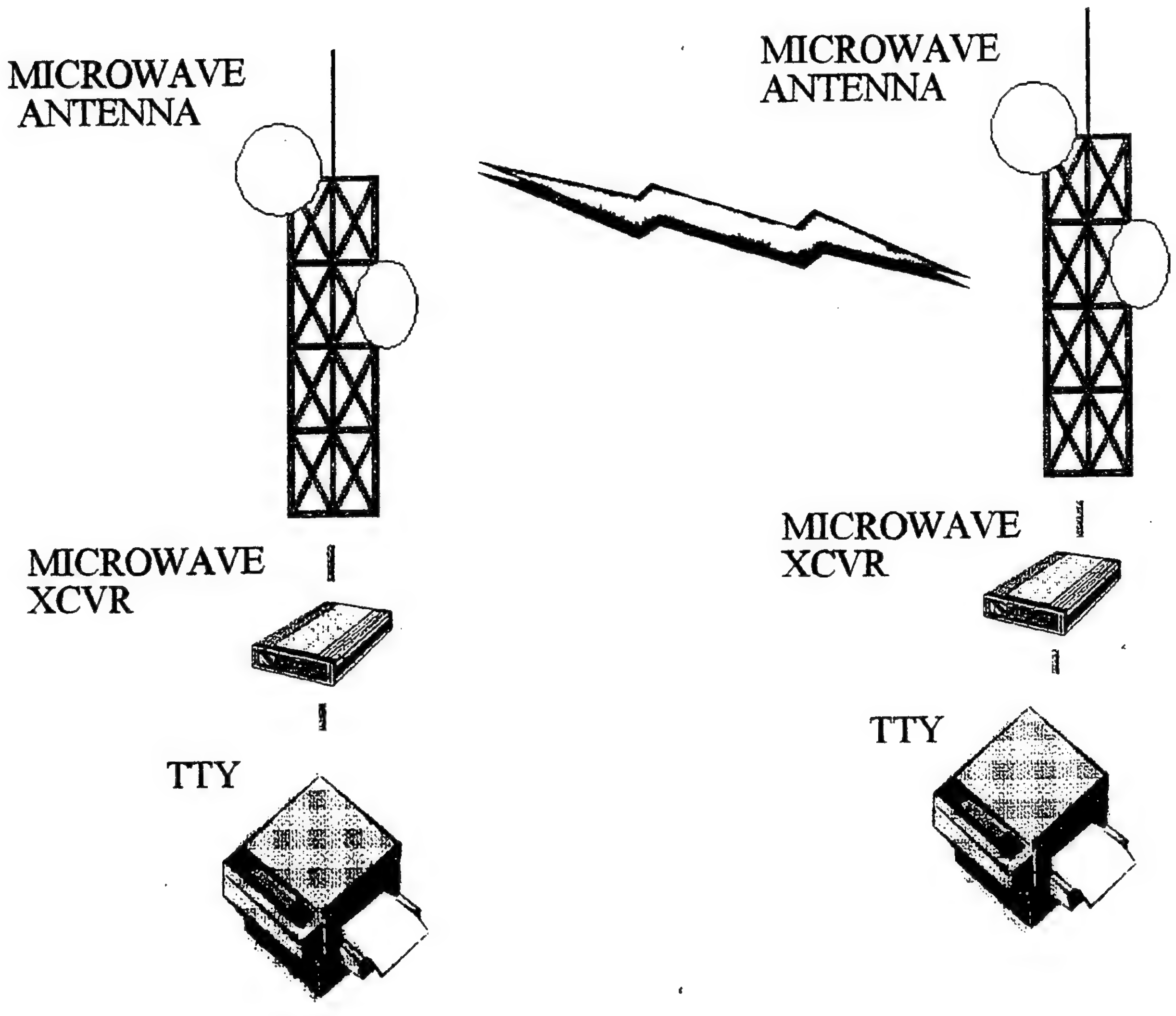
VHF-FM (VOICE) VESSEL TRAFFIC SYSTEM (VTS)/ NATIONAL DISTRESS SYSTEM (NDS)



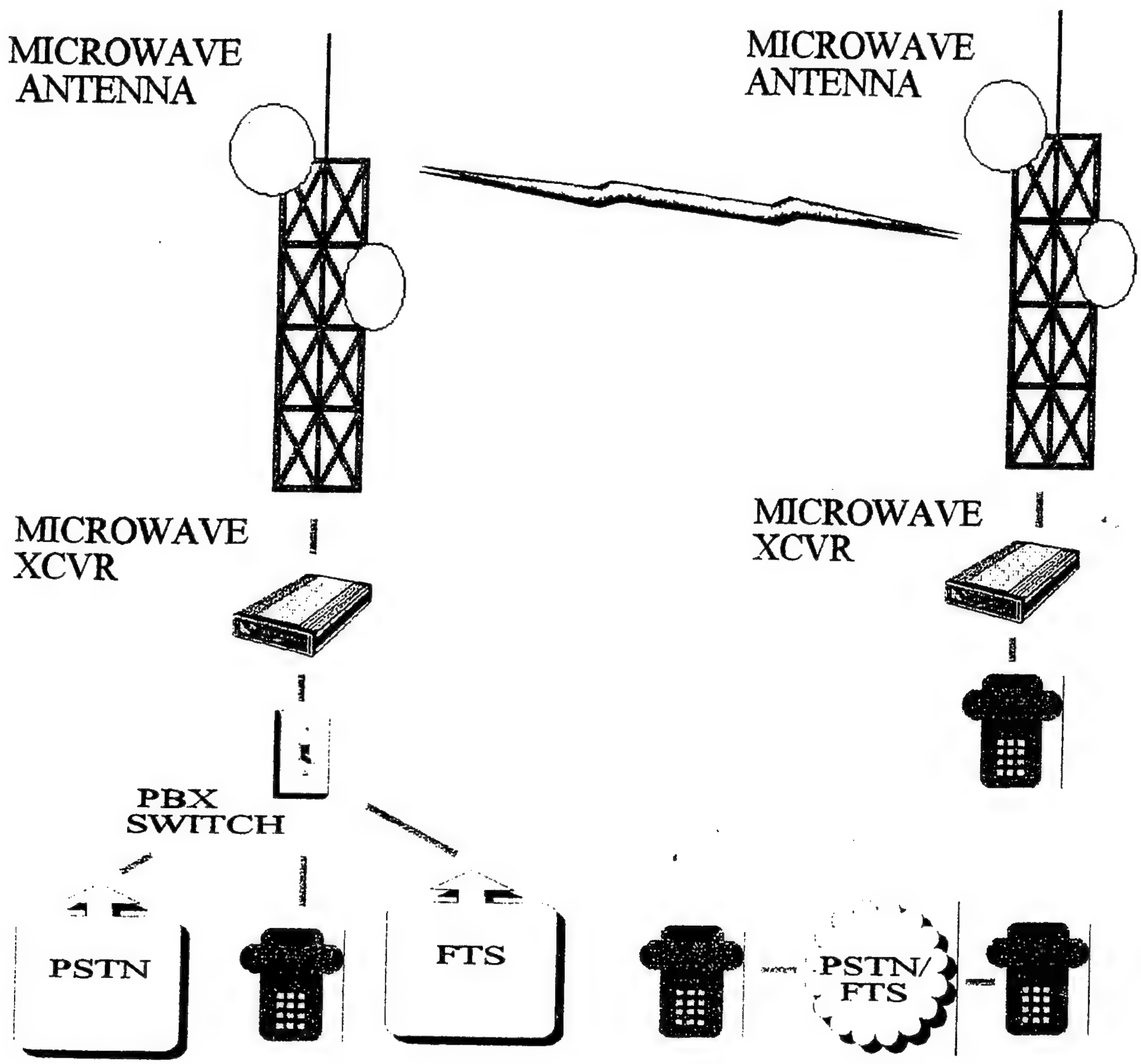
AIR CONTROL
UHF VOICE/DATA



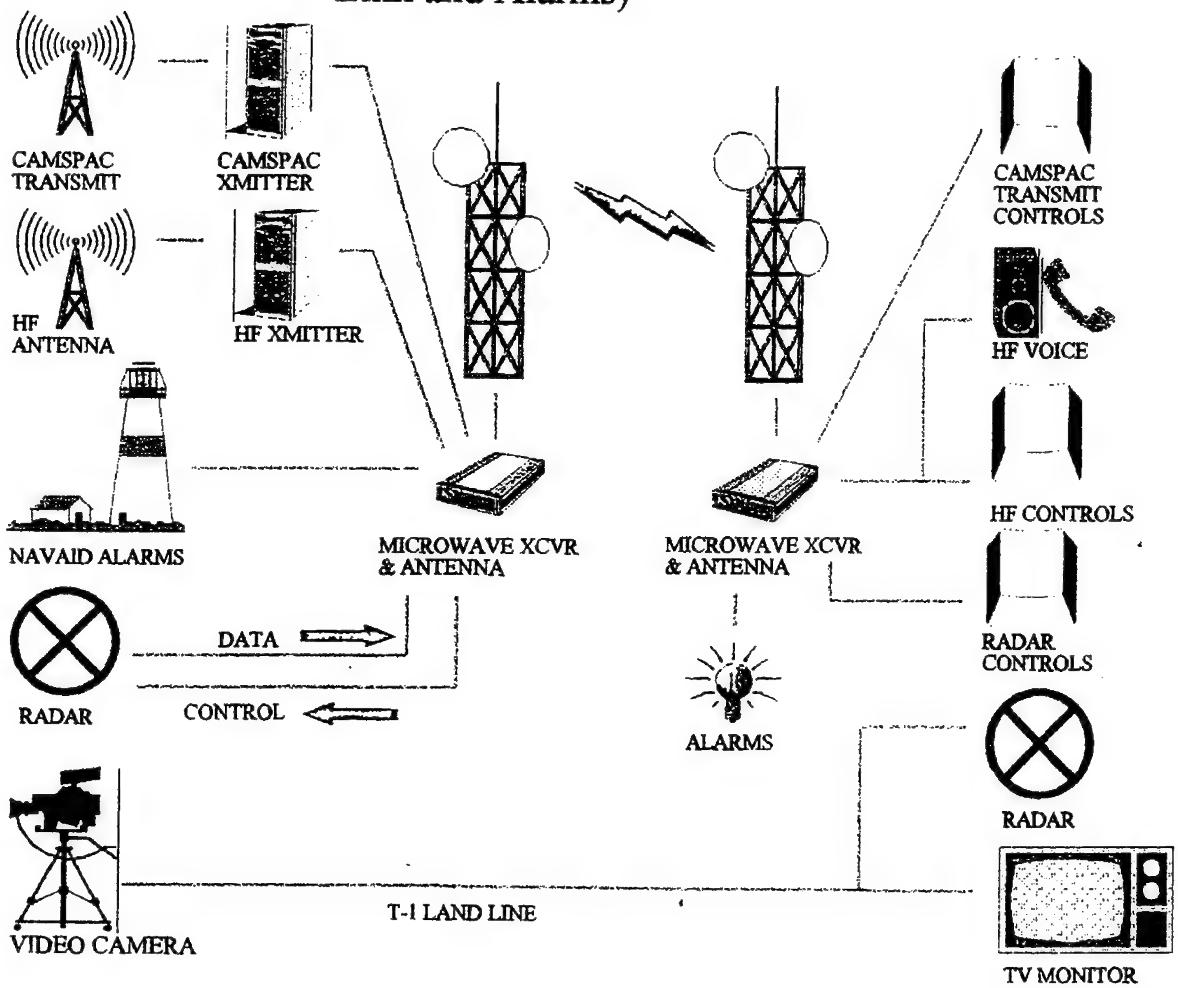
HSTN / HDN


MICROWAVE
ANTENNA
MICROWAVE
ANTENNA
MICROWAVE
XCVR
MICROWAVE
XCVR
TTY
TTY

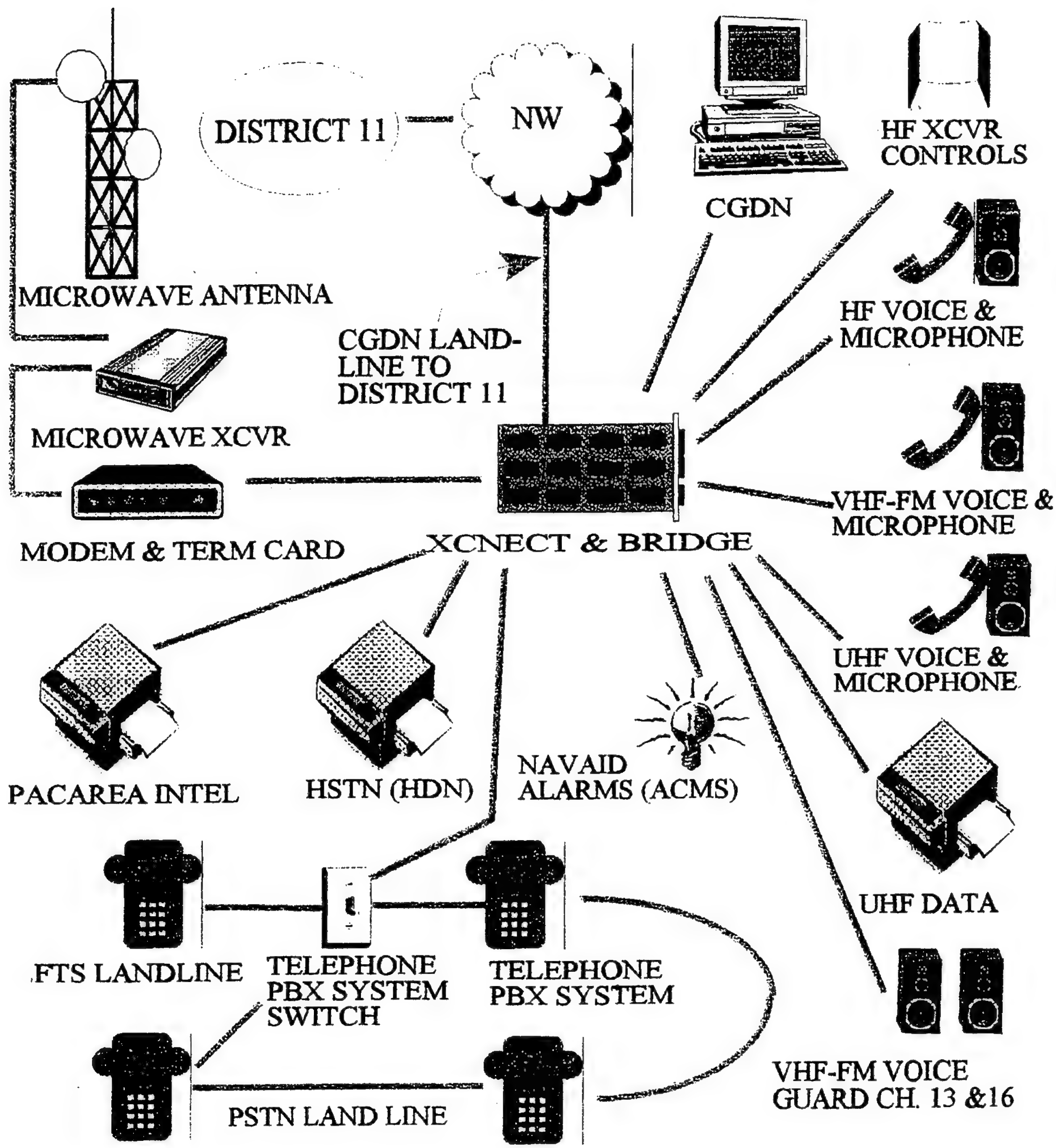
CGI PHONE
(TELEPHONE PBX)



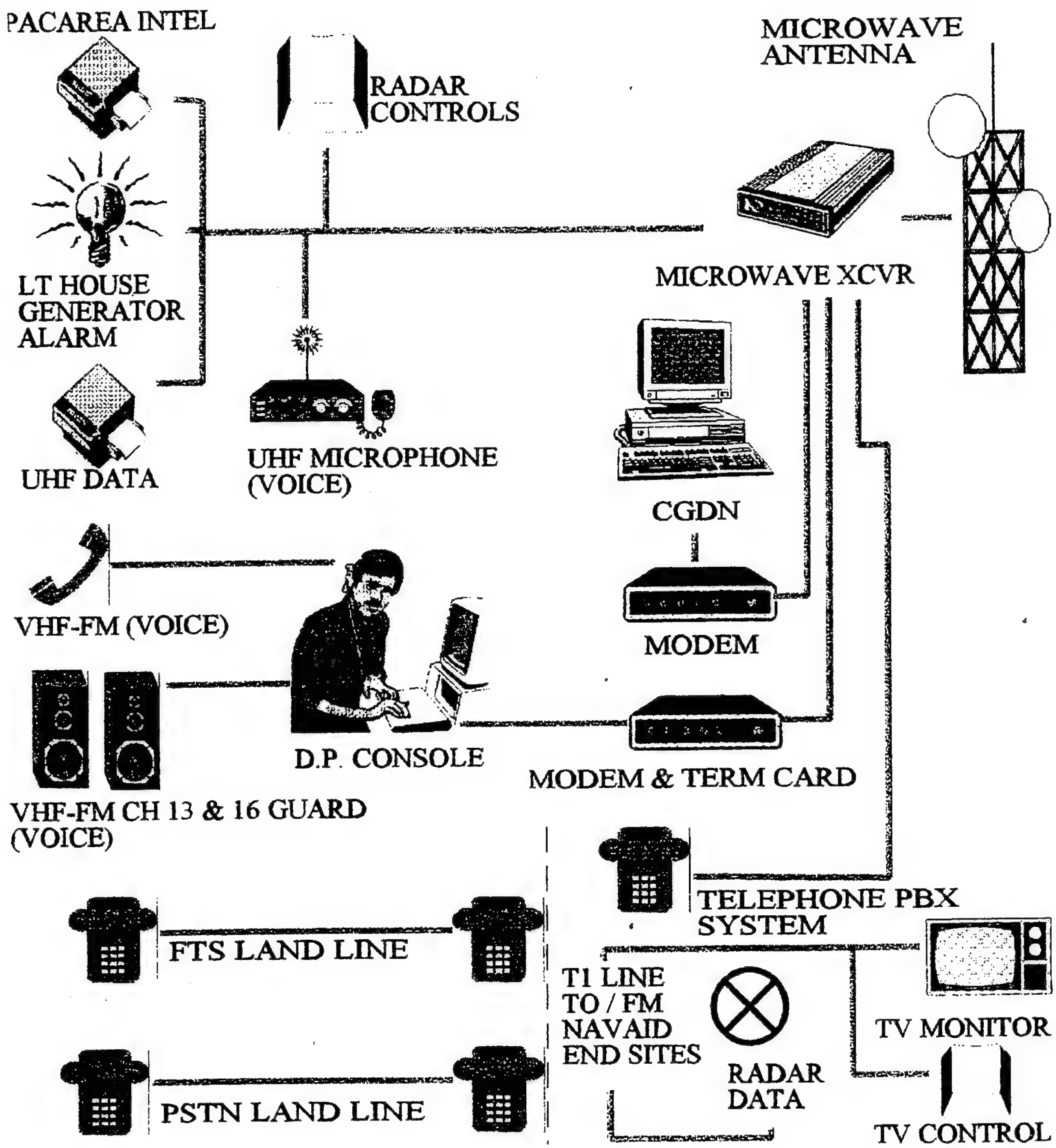
MISCELLANEOUS SYSTEM (HF, Video, Radar, CAMSPAC Link and Alarms)



GROUP S. F. & C.G. ISLAND

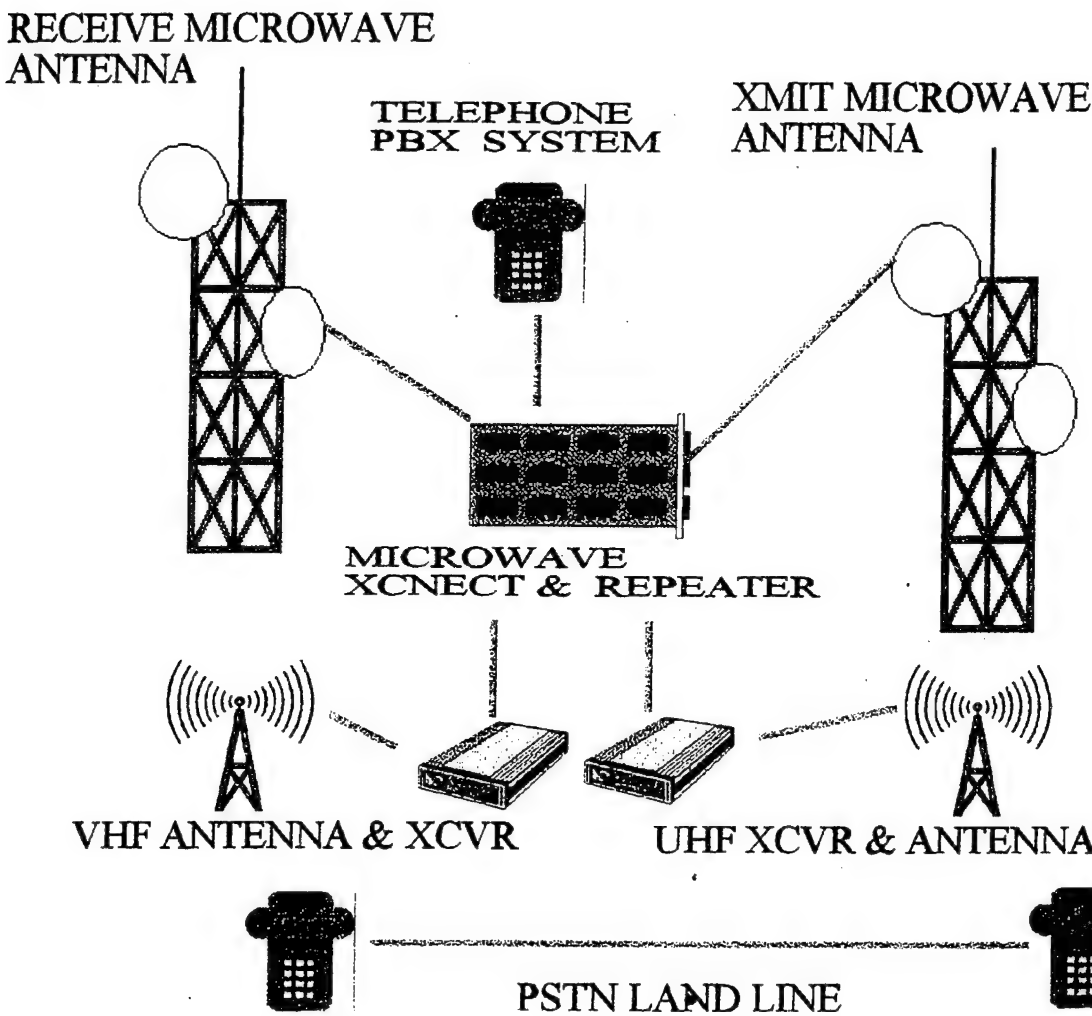


STATION

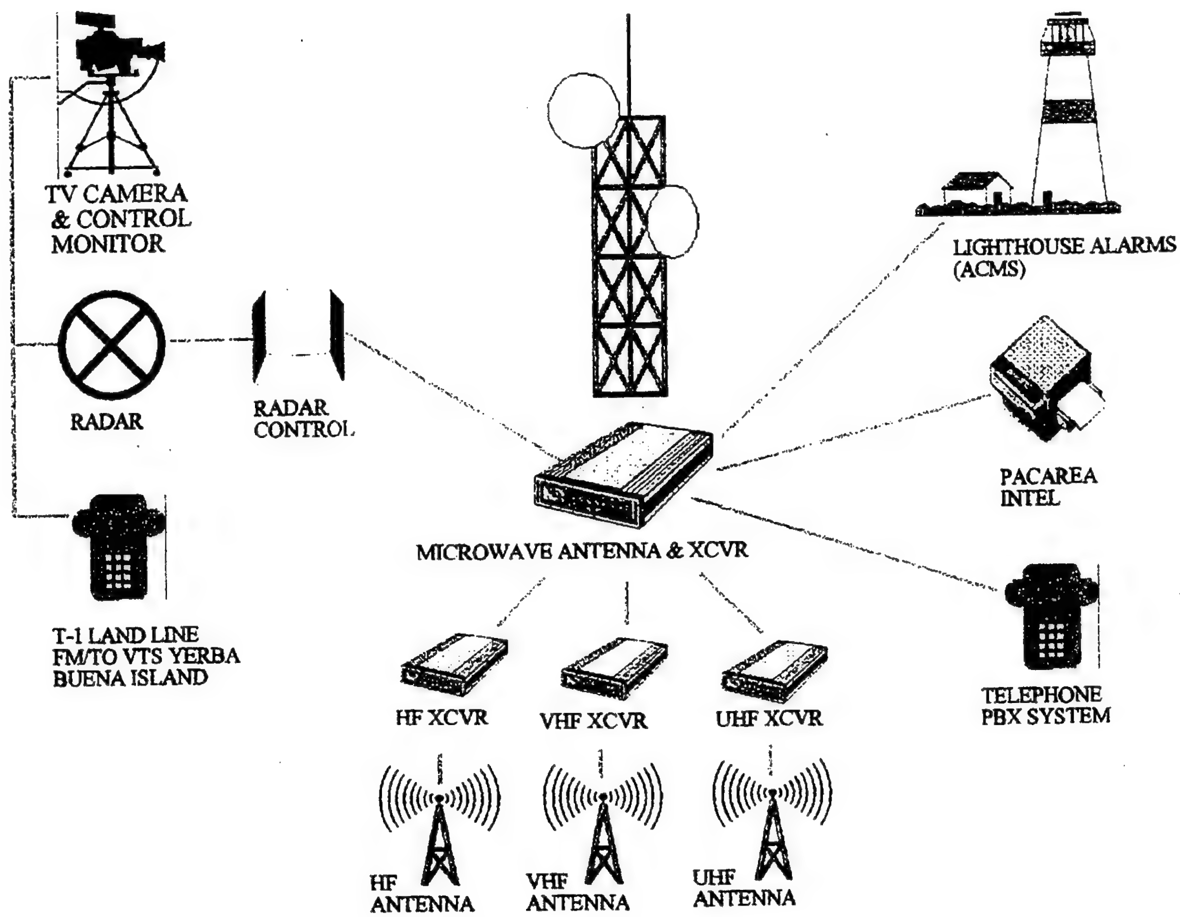


PACAREA INTEL
RADAR CONTROLS
MICROWAVE ANTENNA
LT HOUSE GENERATOR ALARM
MICROWAVE XCVR
UHF DATA
UHF MICROPHONE (VOICE)
CGDN
VHF-FM (VOICE)
MODEM
D.P. CONSOLE
MODEM & TERM CARD
VHF-FM CH 13 & 16 GUARD (VOICE)
TELEPHONE PBX SYSTEM
FTS LAND LINE
T1 LINE TO / FM NAVAID END SITES
TV MONITOR
RADAR DATA
PSTN LAND LINE
TV CONTROL

RELAY HIGH SITE



NAVAID/END SITE



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